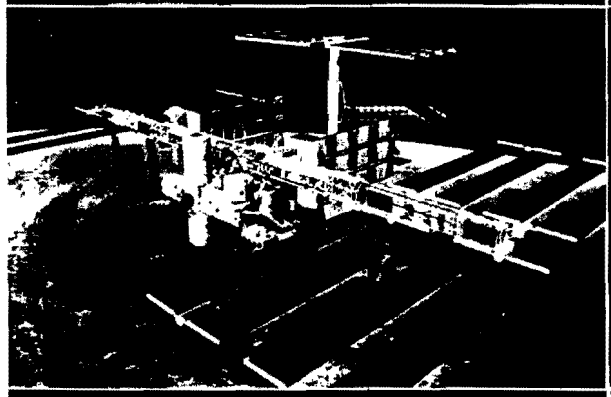

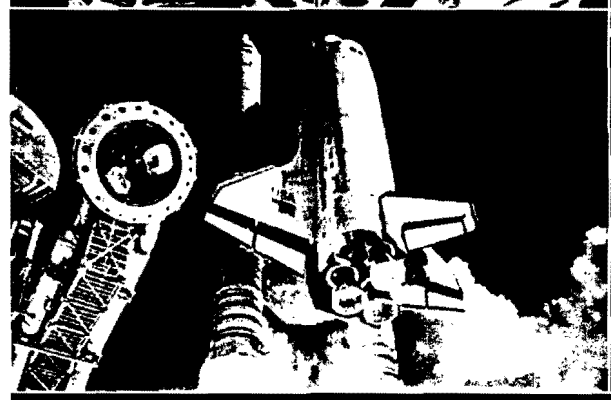

FISCAL YEAR 2001 BUDGET ESTIMATES

Agency Summary, Human Space Flight, Science, Aeronautics & Technology, Mission Support, and Inspector General

NASA

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NASA Headquarters	http://www.hq.nasa.gov/
NASA Strategic Plan	http://www.hq.nasa.gov/office/nsp/
NASA Strategic Management Handbook	http://www.hq.nasa.gov/office/codez/strahand/frontpg.htm
Chief Financial Officer	http://ifmp.nasa.gov/codeb/
Budget Request	http://ifmp.nasa.gov/codeb/budget2001/
Public Affairs	http://www.nasa.gov/newsinfo/index.html
Legislative Affairs	http://www.hq.nasa.gov/office/legaff/
Human Resources and Education	http://www.hq.nasa.gov/office/codef/
Procurement	http://www.hq.nasa.gov/office/procurement/
Safety and Mission Assurance	http://www.hq.nasa.gov/office/codeq/
Small and Disadvantaged Business Utilization	http://www.hq.nasa.gov/office/codek/
External Relations	http://www.hq.nasa.gov/office/codei/
Inspector General	http://www.hq.nasa.gov/office/oig/hq/
Aeronautics Enterprise	http://www.aero-space.nasa.gov/
Earth Science Enterprise	http://www.earth.nasa.gov/
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Office of Space Flight	http://www..hq.nasa.gov/osf/
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Ames Research Center	http://www.arc.nasa.gov/
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Wallops Flight Facility	http://www.wff.nasa.gov/
Goddard Institute for Space Studies	http://www.giss.nasa.gov/
Jet Propulsion Laboratory	http://www.jpl.nasa.gov/
Johnson Space Center	http://www.jsc.nasa.gov/
White Sands Test Facility	http://www.wstf.nasa.gov/
Kennedy Space Center	http://www.ksc.nasa.gov/ksc.html
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Marshall Space Flight Center	http://www.msfc.nasa.gov/
Stennis Space Center	http://www.ssc.nasa.gov/
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

NASA'S VISION FOR THE FUTURE

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

NASA's unique mission of exploration, discovery, and innovation has preserved the United States' role as both a leader in world aviation and as the preeminent spacefaring nation. It is NASA's mission to:

- Advance human exploration, use and development of space;
- Advance and communicate scientific knowledge and understanding of the Earth, the Solar System, and the Universe;
- Research, develop, verify and transfer advanced aeronautics, space and related technologies.

The outcomes of NASA's activities contribute significantly to the achievement of America's goals in five key areas:

- Economic growth and security - NASA conducts aeronautics and space research and develops technology in partnership with industry, academia, and other federal agencies to keep America capable and competitive.
- Increased understanding of science and technology – NASA communicates widely the content, relevancy, and excitement of our mission and discoveries to inspire and increase the understanding and the broad application of science and technology.
- Sustainable Development of the Environment - NASA studies the Earth as a planet and as a system to understand global climate change, enabling the world to address environmental issues.
- Educational Excellence - NASA involves the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds.
- Peaceful Exploration and Discovery - NASA explores the Universe to enrich human life by stimulating intellectual curiosity, opening new worlds of opportunity, and uniting nations of the world in this quest.

STRATEGY FOR ACHIEVING OUR GOALS

The NASA budget request for FY 2001 continues the President's commitment to invest in the future. This budget request recognizes the enormous potential for investments in the civil space and aeronautics program to benefit this country. The President's 1996 National Space Policy outlined a strong and stable program in space that will ensure America's role as the world's space leader. The Space Policy reaffirmed the United States' commitment to the International Space Station, to the next generation of launch vehicle programs, to an aggressive Space Science program, and to the continuing commitment to a long-term program of environmental monitoring from space. The President's strategy for investing in science and technology, encompassing goals which emphasize world leadership in science, mathematics and engineering, economic growth, improved environmental quality, and harnessing information technology continues as the framework for development of federal science and technology policy. The President's

budget request for NASA for FY 2001 fully supports these goals.

The NASA budget request for FY 2001 is reflected in four appropriations:

Human Space Flight - providing funding for the Space Station and Space Shuttle programs, including development of research facilities for the International Space Station and continuing safe, reliable access to space through augmented investments to improve Space Shuttle safety, support of payload and expendable launch vehicle (ELV) operations, and other investments including innovative technology development and commercialization.

Science, Aeronautics and Technology - providing funding for NASA's research and development activities, including all science activities, global change research, aeronautics, technology investments, education programs, space operations, and direct program support;

Mission Support - providing funding for NASA's civil service workforce, safety and quality assurance activities, and facilities construction activities to preserve NASA's core infrastructure;

Inspector General - providing funding for the workforce and support required to perform audits and evaluations of NASA's programs and operations.

The NASA Strategic Plan establishes a framework for making management decisions by separating the Agency's programs into four Strategic Enterprises through which we implement our mission and communicate with our external customers: Space Science; Earth Science; Human Exploration and Development of Space; and Aero-Space Technology

Each Enterprise, similar to the strategic business units employed by the private sector, has a unique set of strategic goals, objectives, and concerns, and a unique set of primary external customers. NASA also provides capabilities that are required for each Enterprise to achieve its goals and meet the needs of their customers. These agency-level activities serve multiple Enterprises and the strategies of these functions are driven primarily by the strategic plans of the Enterprises. The fundamental values of excellence, responsibility, teamwork, trust, and honor form the bedrock of all of NASA's activities.

NASA's Strategic Plan transcends its organizational structure. Each of the Strategic Enterprises seeks to respond to a unique customer community. Each of the Enterprises has its own set of technology needs which are closely linked to performing future planned missions while reducing cost and technical risk. At the same time, there is considerable synergy between the Enterprise activities, which strengthens each Enterprise. The Strategic Enterprises comprise an integrated national effort. Synergism of broad purposes, technology requirements, workforce skills, facilities, and many other dimensions was the basis for amalgamating these activities within NASA in the National Aeronautics and Space Act in 1958, and the benefits remain strong today.

A broad description of the focus of each Strategic Enterprise follows:

Space Science - The activities of the Space Science Enterprise seek answers to fundamental questions, such as understanding the

origin and evolution of the universe and our solar system, if there are planets around other stars, whether the Earth is unique, and if life exists elsewhere. The quest for this information, and the answers themselves, maintains scientific leadership, excites and inspires our society, strengthens education and scientific literacy, develops and transfers technologies to promote U.S. competitiveness, fosters international cooperation to enhance programs and share their benefits, and sets the stage for future space ventures.

Earth Science The activities that comprise this Enterprise are dedicated to understanding the total Earth system and the effects of humans on the global environment. This pioneering program of studying global climate change is developing many of the capabilities that will be needed for long-term environment and climate monitoring and prediction. Governments around the world need information based on the strongest possible scientific understanding. The unique vantage-point of space provides information about the Earth's land, atmosphere, ice, oceans, and biota as a global system, which is available in no other way. In concert with the global research community, the Earth Science Enterprise is developing the understanding needed to support the complex environmental policy decisions that lie ahead.

Human Exploration and the Development of Space - The Human Exploration and Development of Space Enterprise seeks to bring the frontiers of space fully within the sphere of human activities. HEDS conducts research and development to sustain a permanent human presence in space in low-Earth orbit. HEDS will use the environment of space for research on biological, chemical and physical processes and facilitates the development of space for commercial enterprise. In pursuit of these goals, HEDS delivers knowledge and technologies that help to improve medical care and industrial processes on Earth while strengthening education and scientific literacy.

Aero-Space Technology - - The Aero-Space Technology Enterprise features the Aeronautics and Space Transportation programs. NASA, and its predecessor, the National Advisory Committee for Aeronautics, have worked closely with U.S. industry, universities, and other Federal agencies to give the United States a preeminent position in Aeronautics. The Aeronautics program will pioneer the identification, development, verification, transfer, application and commercialization of high-payoff aeronautics technologies. Activities pursued as part of this Enterprise emphasize customer involvement, encompassing U.S. industry, the Department of Defense, and the Federal Aviation Administration. NASA is playing a leadership role as part of a Government-industry partnership to develop breakthrough technology that will help the aviation community cut the fatal accident rate five-fold within ten years and ten-fold within twenty years. NASA also supports the development of technologies to address airport crowding, aircraft engine emissions, aircraft noise, and other issues that could constrain future U.S. air system growth. The Space Transportation Technology program will develop new technologies aimed at access to space. The targeted technologies will reduce launch costs dramatically over the next decade, as well as increase the safety and reliability of current and future generation launch vehicles. Additionally, new plateaus of performance for in-space propulsion will be established, while reducing cost and weight.

NASA's ability to inspire and expand the horizons of present and future generations rests on the success of these efforts to maintain this nation's leadership in space. In order to ensure the stability to manage and execute programs within budget and schedule, NASA is seeking multi-year appropriations for the International Space Station.

PLANS AND ACCOMPLISHMENTS

HUMAN SPACE FLIGHT

International Space Station

The International Space Station (ISS) is an international laboratory in low Earth orbit on which American and international crews will conduct unique scientific and technological investigations in a microgravity environment. The goal of the Station is to support activities requiring the unique attributes of humans in space and establish a permanent human presence in Earth orbit. The proposed budget provides multi-year funding through an advanced appropriation for the continued development of the vehicle and its research components and for current operations, assembly and utilization of the station. With the first launches successfully completed, the budget includes funding to keep subsequent assembly missions on schedule for completion in 2004-2005 and provide a long-term solution to the safe return of the full complement of station crewmembers in the event of an emergency.

In FY 1999, successful launches of the first two components of the Station - the FGB control module and the first node - were completed in November and December respectively, and the elements were assembled in orbit and activated. A third flight delivering supplies to support the first crews was successfully performed in May 1999. Flight hardware elements for the next six U.S. assembly launches -- the Z1 and SO trusses, the control moment gyros, the first photo-voltaic array and battery sets, initial thermal radiators, communication equipment, the U.S. Laboratory, the mobile servicing system and the Multi-Purpose Logistics Carrier -- were delivered to the launch site and the first phases of multi-element integrated testing (MEIT) were completed. Crew training, payload processing, hardware element processing, and mission operations were supported. In 2000, fabrication of flight hardware, qualification testing, assembly, integration and mission operations will all continue. Difficulties with completion of U.S. MEIT testing, coupled with delays to the Russian Service Module, caused by recent failures of the Proton launch system, have delayed planned assembly and expedition flights. The Service Module will be launched in mid- to late-2000, and assembly and expedition flights will follow. The Russian launch of a Soyuz vehicle will enable permanent occupation of the station with rotating crews of three. In 2001 plans are to launch seven U.S. missions to station, including the lab module. Phase 2 of the station assembly will be completed with the launch of the airlock, and preparations will continue for the start of Phase 3 and the first shuttle mission dedicated to research utilization in late 2001/early 2002.

As part of the FY 1999 operating plan, Russian Program Assurance (RPA) was re-established within the Space Station budget line. The RPA funding provides contingency activities to address ISS program requirements resulting from delays or shortfalls on the part of Russia in meeting its commitments to the ISS program. The first step in the contingency plan is to protect against a potential further delay in the Russian Service Module (SM) and its capabilities. The ISS program is purchasing, from the U.S. Naval Research Laboratory (NRL), an interim control module (ICM) to provide backup attitude control and reboost functions for the ISS. Additionally, the Shuttle fleet is being configured for reaction control system (RCS) interconnectivity modifications to enable greater Shuttle reboost capability to the ISS. A permanent U.S. propulsion capability is being developed for implementation in the 2002 timeframe. This includes a propulsion module, carriers, and activities to support propulsion logistics. An agreement negotiated with the Russians in 1999 will provide needed hardware and services to the U.S., including services to provide additional crew return capability when the Station attains the ability to support a permanent crew of six.

Phase 1 development of a crew return vehicle (CRV), to provide the U.S. capability to return up to seven crew members, is initiated in 2000. Design and operational technologies tested and demonstrated in Phase 1 will reduce CRV development risk. The X-38, including the space test flight in 2002, is being transitioned to merge with the ISS CRV funding in 2000 because of the overlap of CRV and X-38 technology developments. Pending a final decision to develop an X-38 based CRV, Phase 2 development funding will be included in the Aero-Space Technology budget estimates, beginning in FY 2002.

Payload and ELV Support

Activities funded by the payload carriers and support budget provide the required technical expertise and facilities to perform the payload buildup, test and checkout, integration, servicing, transportation and installation and deintegration in the Shuttle launch vehicle. In FY 1999, activities were provided for four Space Shuttle missions, including the first American segment of the ISS, and payload processing support activities and facilities for six manifested major payloads. In FY 2000, launch and landing payload support activities will be provided for six Space Shuttle missions including the Hubble Space Telescope (HST-03A) launch, the Shuttle Radar Topography Mission (SRTM) launch, and three assembly flights for the ISS. In FY 2001, launch and landing payload support activities will be provided for nine Space Shuttle missions, including seven ISS assembly and utilization flights. During this period, five pallets will be used in Space Shuttle missions, including the fourth HST servicing mission and three of the ISS assembly flights. In FY 2000 and 2001, over 20 major and secondary payloads will be supported, including major hardware for ISS assembly.

The Expendable Launch Vehicle (ELV) Mission Support budget provides funds for acquiring requisite launch services to meet all NASA requirements and for technical insight of commercially provided launch services. Advanced mission design/analysis and leading edge integration services are provided for the full range of NASA missions under consideration for launch on ELVs. During FY 1999, 10 ELV launches and 1 secondary ELV missions were successfully launched. Support for 13 missions, including Tracking and Data Relay Satellite-H (TDRS-H), Terra and Geostationary Operational Environmental Satellite-L (GOES-L), and four planetary missions are planned for launch in FY 2000, and integration and technical management of 28 payloads are planned for launch in FY 2000 and FY 2001. Support for 11 missions and 1 secondary payload is planned for FY 2001.

Investments and Support

Beginning in FY 2001, the Human Exploration and Development of Space (HEDS) Commercialization and Technology Initiative will include human space exploration and development activities emphasizing highly innovative technologies, advances in science, and enabling synergistic commercial space development efforts.

A consolidated project activity will begin in FY 2001 to ensure NASA's rocket propulsion test capabilities are properly managed and maintained in world class condition. The project will significantly enhance our ability to properly manage NASA's rocket testing activities and infrastructure across all four participating NASA centers.

Engineering and technical base (ETB) activity will continue to support the institutional capability in the operation of space flight laboratories, technical facilities, and testbeds; to conduct independent safety, and reliability assessments; and to stimulate science and technical competence in the United States.

Space Shuttle
The U.S. Space Shuttle provides several unique capabilities to the United States space program. These include retrieving payloads from orbit for reuse, servicing and repairing satellites in space, launching ISS components and providing an assembly platform in space, and operating and returning space laboratories. In FY 1999, the Space Shuttle launched four flights successfully including the first ISS assembly mission, one resupply flight to the ISS, one microgravity research mission which included the return to space of Senator John Glenn, and the successful deployment of the Chandra-Advanced X-Ray Astrophysics Facility (AXAF).

The six flights manifested in FY 2000 include the emergency HST Servicing Mission 3A which will replace failing gyros on the HST and the Shuttle Radar Topography Mission (SRTM), a joint DOD/NASA payload to study the earth. The Space Shuttle will also visit the ISS four more times, for both assembly and maintenance. Finally, the first crew will begin the permanent occupation and presence aboard the ISS in FY 2000.

Nine flights are planned during FY 2001, including seven ISS assembly and servicing missions. In addition, a dedicated microgravity research flight and another HST Servicing Mission (3B) will be flown.

SCIENCE, AERONAUTICS AND TECHNOLOGY

Space Science
The Space Science program seeks to answer fundamental questions concerning: the galaxy and the universe; the connection between the Sun, Earth and heliosphere; the origin and evolution of planetary systems; and, the origin and distribution of life in the universe. The Space Science program is comprised of a base program of research and development activities, including research and flight mission activities, and major space-based facilities.

In 1999, the Space Science program produced many notable scientific accomplishments. The Hubble Space Telescope fulfilled one of its most important objectives in May 1999, when the Hubble Space Telescope Key Project Team announced the results of their studies, which yielded an estimate of the Hubble constant to within 10% accuracy. The Hubble constant indicates the rate at which the universe is expanding from the primordial "Big Bang" and is one of the most important numbers in cosmology because it is needed to estimate the age and size of the universe. Combining the Hubble constant measurement with estimates of the density of the universe, the team estimated that the universe is approximately 12 billion years old. The Chandra X-ray Observatory (CXO), the third of the four "great observatories," was successfully launched and activated. As soon as science operations began, images showing astonishing detail of X-ray sources were obtained. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, CXO has just begun to investigate some of the most important topics in space science, including the age and size of the universe, dark matter, and X-ray background radiation. Other scientific discoveries related to the structure and evolution of the universe include the detection of "middleweight" black holes that are 100 to 10,000 times as massive as the Sun but occupy less space than the Moon, and the first-ever optical image of a gamma ray burst. Gamma ray bursts are the most powerful explosions in the universe, and for a very short period produce more energy than the rest of the universe combined. Also in 1999, several teams of researchers supported by NASA discovered many new planets orbiting nearby stars, including evidence of the first known planet orbiting a pair of stars. Within our own solar system, the Mars Global Surveyor (MGS) generated the first global three-dimensional view of Mars. These images revealed an impact basin deep enough to swallow Mount

Everest, as well as pathways for water flow. Scientist using MGS' magnetometer discovered surprising evidence of past movement of the Martian crust, further evidence that ancient Mars was a more dynamic, Earth-like planet than it is today. A dramatic time-lapse movie by the Hubble Space Telescope showed, for the first time, seasonal changes on Uranus. The Galileo spacecraft produced new images showing volcanic activity on Jupiter's moon Io, similar to the volcanism that occurred on Earth eons ago. Analysis of data from the Lunar Prospector spacecraft confirmed that the Moon has a small core, supporting the theory that the bulk of the Moon was ripped away from the Earth when an object the size of Mars collided with the Earth. In the field of solar science NASA sponsored scientists using the Japanese Yohkoh spacecraft discovered that an S-shaped structure often appears on the Sun in advance of a coronal mass ejection (CME), a violent eruption that is as powerful as billions of nuclear explosions. The Solar and Heliospheric Observatory (SOHO) spacecraft discovered the source of high-speed solar wind, a stream of electrified gas that affects the Earth's space environment.

To capitalize on these enormous successes during the past year, the President's FY 2001 Budget for NASA once again highlights Space Science. Space Science continues to focus on the Origins program and fundamental questions regarding the creation of the universe and planetary systems and the possibility of life on places other than planet Earth. Planning and technology development continues for the deployment of powerful telescopes to detect Earth-like planets beyond our solar system, for the launch of a mission to directly observe subsurface oceans on Europa, and for future missions to seek evidence of past or present life on Mars. The President's Budget supports two major initiatives in Space Science. The first is an enhanced Solar System Exploration program to establish a sustained presence at multiple locations on and around Mars and other potential research targets. Using advanced outposts of numerous, networked spacecraft, NASA will greatly enhance the science return and overall success of future missions. Eventually, such outposts will bring continuous access to live data and video so researchers and the public can explore and experience other worlds first-hand. The second is the "Living With a Star" Initiative to develop better solar weather forecasting capabilities and to better protect high-tech infrastructure from dangerous events like solar flares.

Development activities continue on the Relativity (Gravity Probe-B) mission, which is currently scheduled for launch in 2001. The Space Infrared Telescope Facility (SIRTF) initiated development in April 1998, with launch planned for December 2001. Development activities on the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) mission continued in 1999, with launch planned in 2000. Development activities on the Stratospheric Observatory for Infrared Astronomy (SOFIA) continue. The upgraded Hubble Space Telescope (HST) is providing new insights into our universe. Funding for HST continues to support operations, as well as preparation for servicing mission 3B in 2001 and servicing mission 4 in 2003.

In Explorer missions, development activities continue for the Microwave Anisotropy Probe (MAP) and Imager for Magnetosphere-to-Aurora Global Exploration (IMAGE) Medium-Class Explorer (MIDEX) missions. MAP will be launched in November 2000, IMAGE in February 2000. Two new MIDEX missions were selected in 1999: Full-sky Astrometric Mapping Explorer (FAME) scheduled for launch in 2004, and Swift, a multi-wavelength observatory for gamma-ray burst astronomy, to be launched in 2003. Three Small Explorer (SMEX) missions continued development in FY 1999: the High Energy Spectroscopic Imager (HESSI) is to launch in 2000; the Galaxy Evolution Explorer (GALEX) will launch in 2001; and the Two Wide-Angle Neutral Atom Spectrometers (TWINS) has been selected as a mission of opportunity, to be launched in 2003 and 2004. These missions emphasize reduced mission costs and accelerated launch schedules.

The Mars Global Surveyor entered Mars orbit in September 1997, the Mars Climate Orbiter was launched in December 1998 and the Mars Polar Lander was launched in January 1999. Unfortunately, the Orbiter was lost while attempting to enter Mars orbit in September 1999, and the Lander was lost during entry, descent and landing in December 1999. Funds are requested for the development of future Mars missions to establish a sustained presence at Mars that will greatly increase the science return and overall success of the Mars program. A review to be accomplished in 2000 will provide the plan for future launches.

In the Discovery program, the fourth mission, Stardust, was launched on schedule in February 1999, and is operating normally during its cruise to comet Wild-2, with the encounter scheduled for 2004. Two Discovery missions selected in 1997 are proceeding on schedule: the Comet Nucleus Tour (CONTOUR) will begin development in CY 2000 and will be launched in 2002; the Genesis solar wind sample return mission has begun development and will be launched in 2001. Two new missions were selected for implementation during 1999: The MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) mission to orbit Mercury; and the Deep Impact mission to fly by and fire an impactor into a comet. Both MESSENGER and Deep Impact are planned for launch in 2004. The President's Budget supports a new class of Discovery micromissions that will also be undertaken in 2001 to complement solar system exploration efforts with more frequent and varied research opportunities.

The Flight Validation program is providing flight demonstrations of critical new technologies which will reduce the mass and cost of future science and spacecraft subsystems, while maintaining or improving mission capabilities. The Deep Space-1 mission was launched in October 1998 and has validated its technologies and completed its primary mission, and is now in an extended mission. The Deep Space-2 mission was launched along with the Mars Polar Lander in January 1999, and was lost, along with the Lander, during entry, descent and landing on Mars in December 1999. The Space Technology-4 mission was terminated during 1999 due to the need to fund higher priority programs within the Space Science Enterprise. Also in 1999, NASA selected the Nanosat Constellation Trailblazer as the Space Technology -5 Flight Validation mission. This mission will feature three very small satellites (each about the size of a large birthday cake), that will fly in formation and test eight technologies in the harsh space environment near the boundary of Earth's protective magnetic field. The Flight Validation program has been restructured to enhance openness and competition as well as to increase the number of opportunities for technologies to be flight-validated. Funding for the restructured program has been increased.

Life and Microgravity Sciences and Applications

This program uses the microgravity environment of space to conduct basic and applied research to understand the effect of gravity on living systems and to conduct research in the areas of fluid physics, combustion science, fundamental physics, materials science and biotechnology. In FY 1999, the program flew one science mission (STS-95) on a Spacehab carrier with ISS precursor science experiments. STS-95 included commercially sponsored research as well as research on the effects of aging conducted in collaboration with the National Institution of Health, National Institute on Aging. FY 1999 has also seen the beginning of ISS assembly. In FY 2000, the Russian Service Module (Zvezda) will be launched, enabling permanent human presence aboard the ISS. In FY 2001, the U.S. laboratory module for the ISS will be launched, which will enable initial life and microgravity hardware and experiments to be established aboard the ISS. This will begin a new era of research. In FY 2001, the President's Budget supports a new Bioastronautics Initiative to accelerate research and develop countermeasures that will improve the health and safety of astronauts aboard the International Space station. Devices and countermeasures developed through this initiative may also have many health benefits on Earth. As assembly of the ISS continues to advance, ISS Crew Health Care System (CHECS) components

will be utilized to provide on-orbit medical, environmental, and countermeasure capabilities for all ISS crew members. In early FY 2001, prior to full research capabilities aboard the ISS, the program will fly a dedicated Space Shuttle research mission that will extend previous Space Shuttle research results and help the program as well as the community prepare for increasing research operations on the ISS.

Earth Science

The purpose of NASA's Earth Science Enterprise (ESE) is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. ESE is pioneering the new interdisciplinary field of research called Earth system science, which recognizes that the Earth's land surface, oceans, atmosphere, ice sheets and *biota* are both dynamic and highly interactive. Earth system science is an area of research with the potential for immense benefit to the nation, yielding new knowledge and tools for weather forecasting, agriculture, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. ESE has established three broad goals to fulfill its purpose: (1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and in situ platforms; (2) disseminate information about the Earth system; and, (3) enable productive use of Earth Science and technology in the public and private sectors.

FY 1999 was a year of substantial scientific accomplishment in our understanding of the major elements that comprise the Earth system. Over the oceans, ESE had several accomplishments. ESE reduced the uncertainty in global rainfall over the tropics (2/3 of global precipitation) by one half, helping improve predictions for short-term weather and global availability of fresh water by improving our understanding of the hydrological cycle; produced near-daily ocean color maps that help us understand the role of oceans in removing carbon dioxide from the atmosphere; documented the waxing and waning of El Nino, enabling seasonal climate prediction; and resumed global measurement of winds at the ocean surface to improve short-term weather prediction and tracking major hurricanes and tropical storms globally. Over the ice caps, researchers determined the thinning and thickening rates for the Greenland ice sheet; provided the first detailed radar mosaic of Antarctica; and provided daily observations of the Polar Regions from space.

Over the land, ESE produced the first satellite-derived assessments of global forest cover, began refreshing the global archive of 30-meter land cover data, and conducted an international field experiment in the Amazonia to help understand the role of vegetation on Earth in removing carbon dioxide from the atmosphere . In the solid Earth, ESE and United States Geological Survey (USGS) measured surface displacement, which can help predict earthquakes. In the atmosphere, ESE continued to measure concentrations of both ozone and ozone-depleting substances and assess the recovery of upper ozone correlation and continued work on a 17-year data record of aerosols and cloud properties toward predicting annual to decadal climate variations. Initial cloud products are available and being used through the LaRC Distributed Active Archive Center (DAAC).

The Earth Observing System (EOS), the centerpiece of Earth Science, is a program of multiple spacecraft, supporting technology and interdisciplinary science investigations to provide a long-term data set of key parameters needed to understand global climate change. The first EOS satellite launches began in 1999 with the launches of Landsat-7, Terra (formerly AM-1), and QuikSCAT. EOS PM-1 (now called Aqua) and Chemistry are on schedule to launch in 2000 and 2002 respectively. Preceding the EOS Aqua launch

are a number of individual satellite and Shuttle-based missions that are helping to reveal basic processes.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy Lidar (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The second pair of ESSP missions, the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations - Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) mission, and Cloudsat, will be launched together in 2003.

Data from Earth Science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. These data are expected to find uses well beyond the Earth Science research community. Therefore, ESE is engaging in a variety of demonstrations of public/private partnerships to demonstrate the utility of Earth Science data to environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local governments and others.

The ESE research and analysis program is essential to the discovery of new concepts and to the design of future missions. ESE research is coordinated through the U.S. Global Change Research Program (USGCRP), the Committee on the Environment and Natural Resources (CENR) and its Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Sciences.

Aero-Space Technology

The mission of this Enterprise is to pioneer the identification, development, verification, transfer, application, and commercialization of high-payoff aerospace technologies. Through its research and technology accomplishments, Aero-Space Technology promotes economic growth and national security through a safe, efficient national aviation system and affordable, reliable space transportation. To meet this challenge, the Enterprise has established three pillar goals. Within these three pillar goals, a set of ten objectives, each with its own roadmap, has been defined to address current and future National needs. The technologies associated with these objectives are pre-competitive, long-term, high-risk research endeavors with high-payoff in terms of market growth, safety, low acquisition cost, consumer affordability and a cleaner environment. The goals of this Enterprise directly support National policy in Aero-Space, documented in the 1999 National R&D Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility and the 1994 National Space Transportation Policy.

The first pillar, Global Civil Aviation, addresses the fundamental, systemic issues in the aviation system to ensure continued growth and development appropriate to the needs of the national and global economies. These systemic issues -- safety, capacity, environmental compatibility, and affordability-cut across markets including large subsonic civil transports, air cargo, commuter and general aviation, and rotorcraft. The second pillar, Revolutionary Technology Leaps, will revolutionize air travel and the way in which aircraft are designed, built, and operated, and addresses the challenges in small aircraft, short-haul transportation; supersonic, transoceanic transportation; design tools, and experimental planes. The third pillar, Access to Space, will enable greater commercial potential of space and the expansion of space research and exploration by significantly reducing the cost of space

transportation systems while improving reliability, operability, responsiveness, and safety.

A major restructuring and replanning of the Aero-Space Enterprise's base R&T program was accomplished during 1999 to integrate the Enterprise's existing space transportation and aeronautics base R&T development programs into a single entity. There were several benefits that accrued from this effort. First, the restructuring better aligned the required technology development efforts with our core competencies and brought the expertise resident in the Aeronautics Research Centers to bear on the technological challenges associated with space transportation. Second, the integration of the space and aeronautics development needs resulted in a synergistic technology development plan that better utilized our resources, eliminated overlaps, and allowed dual use, between the space transportation and aeronautics users, to be planned up front rather than relying on serendipitous events.

The President's FY 2001 Budget for NASA increases investments in technology development activities that will address the challenges (safety, environmental impact, capacity, and space transportation costs) that face the aero-space community.

The Administration's request supports the development and deployment of Smart Air Transport System (SATS) technologies that could enable a revolution in accessibility and mobility in America. The product of the SATS (Phase I) Program will demonstrate the technological potential for transportation-driven economic development throughout the nation.

The Administration's request also supports a new Quiet Airplane Technology program will build upon the highly successful noise reduction efforts that were begun in the AST program and maintain the progress toward meeting the Enterprise's Noise Reduction Goal. The achievement of these goals will support an air transportation system that contains objectionable aircraft noise within airport boundaries.

By 2005, NASA will conduct a competitive launch services procurement to support the launch requirements of human spaceflight operations -- The 2nd Generation RLV Focused Program. The objectives will be to dramatically improve safety while significantly reducing the cost of such launch services, and to eliminate the current need for the Government to own and operate the full system. The President's Budget includes new funding for a Space Launch Initiative to support this competition and fulfills a 1994 National Space Transportation Policy guideline calling for government and private sector decisions by 2000 on development of a operational, next-generation reusable launch system.

As part of NASA's response to the national goal of reducing aircraft accidents by a factor of 5 by 2001, NASA increased its safety base R&T efforts in order to provide a foundation for a focused safety program beginning in FY 2000. In 1999, the base R&T programs matured these required safety related technologies to the point where they were successfully transferred to the focussed Aviation Safety Program (AvSP) which begins in FY 2000. These technologies will provide the foundation for the focused safety development efforts in the future. They also will result in some near-term achievements. For example, in FY 1999, the causes of controlled flight into terrain (responsible for 30% of fatal accidents) were identified and 13 contracts issued via a NASA research announcement (NRA) to develop and demonstrate approaches for fully operational and certifiable synthetic vision and health management systems. Also in FY 1999, the preparations for flight evaluation of a crew-centered synthetic vision display were completed and a study initiated to understand the applicability of synthetic vision to General Aviation (GA) type aircraft was begun. In FY 2000, the AvSP program will produce an icing training program for GA and commuter pilots, complete a flight evaluation of an

initial national capability for digital data link and graphical display of weather information, and demonstrate a concept for the integration of air traffic control runway incursion information onto aircraft flight deck displays. In FY 2001, the AvSP will complete a laboratory demonstration of a fuel system modification to reduce flammability, define the architecture for an integrated onboard health management system, and down-select synthetic vision concepts suitable for retrofit in commercial, business, and general aviation aircraft. The base R&T will continue to develop the technologies that will contribute to the FY 2007 goal. For example, in FY 2001, NASA will downselect ground-based remote sensor technologies for a prototype ground-system to sense icing conditions and continue work on a related computer.

NASA also continued its efforts to reduce the environmental impact associated with aviation systems. In FY 1999, in partnership with industry, a demonstration in an engine test rig of a low emission combustor that produced a 50% reduction in oxides of nitrogen (NOx) emissions was successfully demonstrated. The Ultra Efficient Engine Technology (UEET) program will carry this effort forward and demonstrate a system that achieves significant reductions in NOx and carbon dioxide (CO2) emissions in FY 2001. The UEET is a focused program that begins in FY 2000 and is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical, reliable and environmentally compatible U.S. aircraft.

Similarly with noise, in FY 1999, NASA validated an Aircraft Noise Impact model and demonstrated that improved high-lift systems in combination with advanced operational procedures have the potential to reduce community impact by the equivalent of 2-4 db source noise reduction. In 2000, NASA will validate the technologies required to reduce community noise impact by up to 10 dB relative to 1992 technology.

In 1999, the Aviation System Capacity program conducted field evaluation of an initial demonstration of Aircraft Vortex Spacing System (AVOSS) technologies with transport of vortices and class-wise spacing features that have the potential to reduce approach spacing standards. In FY 2000, NASA will demonstrate all technologies in a realistic Terminal Area environment achieving a 12-15% increase in single runway throughput and proving the ability to space aircraft closer than 3,400 feet on parallel runways while meeting all Federal Aviation Administration (FAA) safety criteria. In FY 2001, NASA will demonstrate transition airspace decision support tools for: (1) Air Traffic Control (ATC)/Airline operations center and ATC/cockpit information exchange, and (2) conflict resolution.

Building on its world record setting performances, the Environmental Research Aircraft and Sensor technology (ERAST) project in FY 1999 demonstrated a multistage turbo-charged Remotely Piloted Aircraft (RPA) to 60,000 feet for an 8 hour duration. The Centurion solar-powered airplane, a vehicle with a wingspan greater than 200 ft., completed initial low altitude evaluation under battery power. The Centurion solar-powered RPA was modified to a wingspan configuration of greater than 245 ft., named Helios and will continue flight testing in FY 2000. This configuration will be more suitable for extreme endurance as well as short flights to the 100,000 ft altitude. In FY01, the Flight Research program will demonstrate a solar powered RPA at 100,000 ft and complete development of a heavyweight energy storage system under the ERAST project. Both achievements will demonstrate technologies that could provide atmospheric satellites for commercial use, disaster relief efforts such as communication relays and real time sensing, and increase the Nation's capability to make scientific sampling high in the atmosphere.

Also in FY 2000, NASA initiated a new project entitled Revolutionary Concepts (REVCON) to accelerate the exploration of high-risk, breakthrough technologies in order to enable revolutionary departures from traditional approaches to air vehicle design. At the end of FY 1999, three concepts were accepted for inclusion in the REVCON program. Flight of these vehicles will begin in FY 2001 or 2002. Also in FY 2001, NASA will issue the first NRA under REVCON to select the next set of REVCON concepts.

Low-cost space transportation remains the key enabler for a more aggressive civil space program. NASA's Integrated Space Transportation Planning activities have identified a strategy based upon competition, safety, industry leadership and a comprehensive systems approach to NASA requirements. Funding supports aggressive technical risk reduction and advanced development for multiple reusable launch vehicle concepts. Identification and preliminary development of NASA-unique systems and near-term pursuit of alternative access for key Space Station needs are also both critical elements of the Integrated Space Transportation Plan. All of these efforts combined will move NASA closer to a full and open Reusable Launch Vehicle (RLV) competition by 2005 to meet NASA's Human Space Flight needs by the end of the decade.

Under ISTP, the 2nd Generation RLV Focused Program, through the X-33, X-34 and Future-X Pathfinder Programs, continues to develop, apply and demonstrate new technologies that significantly advance the ability of the launch vehicle industry to initiate commercially viable reusable launch systems.

The X-33 and X-34 have completed several major hardware fabrication and test milestones. However, technical difficulties and program replanning have delayed the flight testing of these advanced technology demonstrators. The X-34 is now expected to fly in 2000. The X-33 flight schedule is under review, following the failure of the composite liquid hydrogen tanks during testing. The X-37 complements the X-33 and X-34 vehicles by investigating the orbit-to-Earth and orbital operations regimes of the flight spectrum, and will begin flight tests in 2002.

The Commercial Technology Program's focus in FY 1999 was continued investment of 10-20 percent of the NASA R&D budget in commercial partnerships with industry. Based on experience to date, these commercial partnerships are expected to increase the return on the government's R&D investment, allowing NASA to do more with limited funds, and strengthening the international competitiveness of key industry sectors. In FY 2000 and 2001, the program will continue to emphasize increasing commercial partnerships with industry and continue to refine and expand a technology and partnership database.

Space Operations

The primary goal of Space Operations is to provide highly reliable, cost-effective space operations services in support of NASA's science and aeronautics programs. In addition, support is provided to interagency, international, and commercial space-faring enterprises on a reimbursable basis. The Space Communications Mission and Data Services program is composed of Operations, Mission and Data Service Upgrades, Tracking and Data Relay Satellite Replenishment, and Technology Projects, as well as spectrum management and data standards coordination. Services are provided to a large number of NASA Missions including planetary missions; Human Space Flight missions; near-Earth and Earth-orbiting missions; and sub-orbital and aeronautical flight tests. A Consolidated Space Operations (CSOC) contract was successfully implemented by the Space Operations Management Office at Johnson Space Center, with the Lockheed Martin Space Operations Company. The CSOC provides end-to-end mission and data services to both NASA and non-NASA customers. A total of nine contracts were consolidated at inception, and four more have been

consolidated in FY 2000 to date, with two additional contracts to be consolidated in FY 2001. Management responsibility for all Wide Area Network data distribution services for all Human Space Flight, Earth orbiting and deep space missions and NASA administrative communications was outsourced by CSOC in FY 2000. Development of the TDRS Replenishment Spacecraft is ongoing, with the first satellite scheduled for launch in FY 2000.

Academic Programs
The goal of this program is to promote excellence in America's education system through enhancing and expanding scientific and technological competence. NASA's education programs span the elementary through graduate levels and are directed at both students and faculty. The goal of the Minority University Research Program is to expand opportunities for talented students from underrepresented groups who are pursuing degrees in science and engineering and to strengthen the research capabilities of minority universities and colleges. The range of activities conducted under this program will continue to capture the interest of all students in science and technology, develop talented students at the undergraduate and graduate levels, provide research opportunities for students and faculty members at NASA centers, and strengthen and enhance the research capabilities of the Nation's colleges and universities.

MISSION SUPPORT

Safety, Mission Assurance, Engineering, and Advanced Concepts
The goal of this program is to invest in the safety and success of NASA missions by assuring that sound and robust policies, processes, and tools for safety, reliability, quality assurance, and engineering disciplines are in place and applied throughout NASA. The program also examines long-term technology requirements for NASA's strategic objectives.

Research and Program Management
This activity provides for the salaries, travel support, other personnel expenses of the entire NASA civil service workforce, and includes vital support to the physical plant at the Centers and at NASA Headquarters.

Construction of Facilities
This activity provides for facility construction activities to preserve NASA's infrastructure and enable NASA's missions; environmental compliance and restoration activities, design of facilities projects, and advanced planning and critical functional leadership activities related to future facilities needs. In 1999-2001, the major focus is on eliminating safety-related concerns by undertaking construction projects to repair and modernize the basic infrastructure and institutional facilities at NASA centers. Increasing attention is being given to activities in support of environmental compliance and restoration requirements. A key project in this area is the Nuclear Regulatory Commission's mandated cleanup of the Plumbrook, Ohio, inactive nuclear reactor site. Planning for this project is underway, with significant clean-up activities slated to begin with funding made available in the FY 2002 appropriation.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 2001 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLAR

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
HUMAN SPACE FLIGHT	**5,480.0**	**5,467.7**	**5,499.9**
INTERNATIONAL SPACE STATION	2,299.7	2,323.1	2,114.5
SPACE FLIGHT OPERATIONS (SPACE SHUTTLE)	2,998.3	2,979.5	3,165.7
PAYLOAD & UTILIZATION OPS	182.0	165.1	--
PAYLOAD & ELV SUPPORT	--	--	90.2
INVESTMENT & SUPPORT	--	--	129.5
SCIENCE, AERONAUTICS & TECHNOLOGY	**5,653.9**	**5,580.9**	**5,929.4**
SPACE SCIENCE	2,119.2	2,192.8	2,398.8
LIFE & MICROGRAVITY SCIENCES & APPS	263.5	274.7	302.4
EARTH SCIENCE	1,413.8	1,443.4	1,405.8
AERO-SPACE TECHNOLOGY	1,338.9	1,124.9	1,193.0
MISSION COMMUNICATIONS SERVICES	380.0	406.3	--
SPACE OPERATIONS	--	--	529.4
ACADEMIC PROGRAMS	138.5	138.8	100.0
MISSION SUPPORT	**2,499.5**	**2,532.2**	**2,584.0**
SAFETY, MSN ASSURANCE, ENGRING & ADV. CONCEPTS	35.6	43.0	47.5
SPACE COMMUNICATION SERVICES	185.8	89.7	--
RESEACH & PROGRAM MANAGEMENT	2,109.6	2,217.6	2,290.6
CONSTRUCTION OF FACILITIES	168.5	181.9	245.9
INSPECTOR GENERAL	**19.6**	**20.0**	**22.0**
TOTAL BUDGET AUTHORITY	**13,653.0**	**13,600.8**	**14,035.3**
TOTAL BUDGET OUTLAYS	**13,663.0**	**13,446.0**	**13,675.0**

*FY 2000 INCLUDES RESCISSION AND SUPPLEMENTAL/ TRANSFER OF $20.2M FROM HSF TO MS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 2001 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS
(IN MILLIONS OF REAL YEAR DOLLARS)

	TOTAL	Human Space Flight	Science, Aero, & Technology	Mission Support	Office of Inspector General
FISCAL YEAR 1999					
VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 1999 (P.L. 105-276)	**13,665.0**	5,480.0	5,653.9	2,511.1	20.0
FY 1999 RESCISSION (P.L. 106-51)	**-11.4**			-11.4	
LAPSE OF FY 1999 UNOBLIGATED FUNDS	**-0.6**			-0.2	-0.4
TOTAL FY 1999 BUDGET PLAN	**13,653.0**	**5,480.0**	**5,653.9**	**2,499.5**	**19.6**
FISCAL YEAR 2000 REQUEST	**13,578.4**	5,638.0	5,424.7	2,494.9	20.8
VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 2000 (P.L. 106-74) AS PASSED BY CONGRESS, DIRECTION INCLUDED IN CONFERENCE REPORT H.R. 106-379	**74.3**	-127.1	182.0	20.2	-0.8
FY 2000 RESCISSION (P.L. 106-113)	**-51.9**	-23.0	-25.8	-3.1	
PROPOSED SUPPLEMENTAL TRANSFER	**0.0**	-20.2		20.2	
TOTAL FY 2000 BUDGET PLAN	**13,600.8**	**5,467.7**	**5,580.9**	**2,532.2**	**20.0**

Note: Human Space Flight activities were submitted to the Congress in FY 2000 as two appropriations per P.L. 105-276 (International Space Station for $2,482.7M and Launch Vehicles and Payload Operations for $3,155.3M). However, these activities were appropriated as Human Space Flight.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

ADMINISTRATIVE PROVISIONS

Notwithstanding the limitation on the availability of funds appropriated for "Human space flight", "Science, aeronautics and technology", or "Mission support" by this appropriations Act, when any activity has been initiated by the incurrence of obligations for construction of facilities as authorized by law, such amount available for such activity shall remain available until expended. This provision does not apply to the amounts appropriated in "Mission support" pursuant to the authorization for [repair, rehabilitation and modification of facilities minor *revitalization and* construction of [new facilities and additions to existing] facilities, and facility planning and design

Notwithstanding the limitation on the availability of funds appropriated for "Human space flight", "Science, aeronautics and technology", or "Mission support" by this appropriations Act, the amounts appropriated for construction of facilities shall remain available until September 30, [2002] 2003.

Notwithstanding the limitation on the availability of funds appropriated for "Mission support" and "Office of Inspector General", amounts made available by this Act for personnel and related costs and travel expenses of the National Aeronautics and Space Administration shall remain available until September 30, [2000] 2001 and may be used to enter into contracts for training, investigations, costs associated with personnel relocation, and for other services, to be provided during the next fiscal year. *Funds for announced prizes otherwise authorized shall remain available, without fiscal year limitation, until the prize is claimed or the offer is withdrawn.*

[Unless otherwise provided for in this Act or in the joint explanatory statement of the committee of conference accompanying this Act, no part of the funds appropriated for 'Human space flight" may be used for the development of the International Space Station in excess of the amounts set forth in the budget estimates submitted as part of the budget request for fiscal year 2000.] (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

GENERAL PROVISIONS

SEC. 423. NASA Full Cost Accounting. Title III of The National Aeronautics and Space Act of 1958. P.L. 85-568 is amended by adding the following new section at the end:

Section 312

"(a) Appropriations for the Administration for fiscal year 2002 and thereafter shall be made in three accounts. "Human Space Flight", "Science, Aeronautics and Technology," and an account for amounts appropriated for the necessary expenses of the Office of Inspector General. Appropriations shall remain available for two fiscal years. Each account shall include the planned full costs of the Administration's related activities

"(b) To ensure the safe, timely, and successful accomplishment of Administration missions, the Administration may transfer amounts for Federal salaries and benefits; training, travel and awards; facility and related costs; information technology services; publishing services; science, engineering, fabricating and testing services; and other administrative services, among accounts, as necessary.

"(c) The Administrator, in consultation with the Director of the Office of Management and Budget, shall determine what balances from the "Mission Support" account are to be transferred to the "Human Space Flight" and "Science, Aeronautics, and Technology" accounts. Such balances shall the be transferred and merged with the "Human Space Flight" and "Science, Aeronautics, and Technology" accounts, and remain available for the period for which originally appropriated."

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

HUMAN SPACE FLIGHT

For necessary expenses, not otherwise provided for, in the conduct and support of human space flight research and development activities, including research, development, operations, and services; maintenance; construction of facilities including [repair, rehabilitation,] *revitalization* and modification of [real and personal property] *facilities, construction of new facilities and additions to existing facilities, facility planning and design,* and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,510,900,000] $5,499,900,000, to remain available until September *30, [2001: Provided,* That $40,000,000 of the amount provided in this paragraph shall be available to the space shuttle program only for preparations necessary to carry out a life and micro-gravity science mission, to be flown between STS-107 and December 2001] *2002. For necessary expenses of the International Space Station, to become available on October 1 of the fiscal year specified and remain available for that and the following fiscal year, as follows: for fiscal year 2002, $1,858,500,000, for fiscal year 2003, $ 1,452,500,000, for fiscal year 2004, $1,327,000,000; and for fiscal year 2005, $1,275,000,000. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)*

SCIENCE, AERONAUTICS AND TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of science, aeronautics and technology research and development activities, including research, development, operations, and services; maintenance; construction of facilities including [repair, rehabilitation] *revitalization,* and modification of [real and personal property] *facilities, construction of new facilities and additions to existing facilities, facility planning and design,* and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,606,700,000] $5,929,400,000, to remain available until September 30, [2001] 2002. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

MISSION SUPPORT

For necessary expenses, not otherwise provided for, in carrying out mission support for human space flight programs and science, aeronautical, and technology programs, including research operations and support; maintenance; construction of facilities including [repair, rehabilitation,] revitalization and modification of facilities, [minor construction of new facilities and additions to existing facilities, facility planning and design, environmental compliance and restoration, and acquisition or condemnation of real property, as authorized by law; program management, personnel and related costs, including uniforms or allowances therefore, as authorized by 5 U.S.C. 5901-5902; travel expenses; purchase, lease, charter, maintenance, and operation of mission and administrative aircraft; not to exceed [$35,000] $40,0000 for official reception and representation expenses; and purchase (not to exceed 33 for replacement only) and hire of passenger motor vehicles, [$2,515,100,000] $2,584,000,000 to remain available until September 30, [2001] 2002. *(Departments of* Veterans *Affairs* and Housing and *Urban Development, and Independent Agencies Ap*propriations *Act, 2000.)*

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, as amended, *[$20,000,000] $22,000,000. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 ESTIMATES

DISTRIBUTION OF PROGRAM AMOUNT BY INSTALLATION
(Thousands of Dollars)

	Total			Human Space Flight			Science, Aeronautics and Technology			Mission Support		
	1999	2000	2001	1999	2000	2001	1999	2000	2001	1999	2000	2001
Johnson Space Center	4,279,259	4,105,814	4,112,307	3,634,561	3,389,731	3,312,300	246,897	307,999	399,427	397,801	408,084	400,580
Kennedy Space Center	941,666	919,041	1,043,816	354,365	378,168	405,900	288,682	239,193	339,591	298,619	301,680	298,325
Marshall Space Flight Center	2,312,511	2,303,352	2,346,142	1,322,539	1,514,700	1,497,800	622,932	458,378	502,277	367,040	330,274	346,065
Stennis Space Center	163,185	167,379	168,036	39,750	41,900	53,300	69,416	68,984	54,551	54,019	56,495	60,185
Ames Research Center	617,522	612,477	693,434	45,800	51,600	80,900	379,548	368,243	398,404	192,174	192,634	214,130
Dryden Flight Research Cent	187,793	210,466	217,837	4,600	7,300	10,800	121,881	137,311	139,002	61,312	65,855	68,035
Langley Research Center	631,850	566,709	645,827	7,185	800	4,100	397,293	317,597	376,247	227,372	248,312	265,480
Glenn Research Center	589,763	551,165	599,706	41,150	40,900	75,200	335,766	290,179	291,716	212,847	220,086	232,790
Goddard Space Flight Center	2,286,192	2,269,788	2,277,958	18,200	9,300	10,300	1,841,830	1,864,565	1,868,698	426,162	395,923	398,960
Jet Propulsion Laboratory	1,143,217	1,263,830	1,434,835	6,200	12,135	14,500	1,113,818	1,224,810	1,393,460	23,199	26,885	26,875
Headquarters	480,442	610,798	473,402	5,650	21,166	34,800	235,837	303,636	166,027	238,955	285,996	272,575
Undistributed:												
Construction of Facilities:												
Various locations	0	0	0									
Inspector General	19,600	20,000	22,000									
TOTAL NASA	13,653,000	13,600,819	14,035,300	5,480,000	5,467,700	5,499,900	5,653,900	5,580,895	5,929,400	2,499,500	2,532,224	2,584,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

The FY 2001 multi-year budget estimate is submitted in accordance with the NASA FY 1989 Authorization Law (P.L. 100-685).

	1999 OPLAN 12/23/99	*2000 OPLAN REVISED	2001 PRES BUDGET	2002	2003	2004	2005
HUMAN SPACE FLIGHT	**5,480.0**	**5,467.7**	**5,499.9**	**5,387.6**	**4,939.0**	**4,817.4**	**4,686.3**
INTERNATIONAL SPACE STATION	2,299.7	2,323.1	2,114.5	1,858.5	1,452.5	1,327.0	1,275.0
SPACE FLIGHT OPERATIONS (SPACE SHUTTLE)	2,998.3	2,979.5	3,165.7	3,307.8	3,264.9	3,253.3	3,169.5
PAYLOAD UTILIZATION AND OPERATIONS	182.0	165.1					
PAYLOAD AND ELV SUPPORT			90.2	90.3	91.5	97.0	101.7
INVESTMENTS & SUPPORT			129.5	131.0	130.1	140.1	140.1
SCIENCE, AERONAUTICS AND TECHNOLOGY	**5,653.9**	**5,580.9**	**5,929.4**	**6,388.9**	**6,993.9**	**7,571.3**	**7,913.5**
SPACE SCIENCE	2,119.2	2,192.8	2,398.8	2,606.4	2,961.4	3,298.8	3,577.9
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	263.5	274.7	302.4	300.3	304.1	323.2	326.0
EARTH SCIENCE	1,413.8	1,443.4	1,405.8	1,332.5	1,293.3	1,303.4	1,306.3
AERO-SPACE TECHNOLOGY	1,338.9	1,124.9	1,193.0	1,548.9	1,948.8	2,244.7	2,302.6
MISSION COMMUNICATION SERVICES	380.0	406.3					
SPACE OPERATIONS			529.4	500.8	386.3	301.2	300.7
ACADEMIC PROGRAMS	138.5	138.8	100.0	100.0	100.0	100.0	100.0
MISSION SUPPORT	**2,499.5**	**2,532.2**	**2,584.0**	**2,666.2**	**2,812.7**	**2,892.2**	**2,945.1**
SAFETY, MISSION ASSURANCE, ENGINEERING AND ADVANCED CONCEPTS	35.6	43.0	47.5	51.5	51.5	51.5	51.5
SPACE COMMUNICATION SERVICES	185.8	89.7					
RESEARCH AND PROGRAM MANAGEMENT	2,109.6	2,217.6	2,290.6	2,383.7	2,482.2	2,569.7	2,662.6
CONSTRUCTION OF FACILITIES	168.5	181.9	245.9	231.0	279.0	271.0	231.0
INSPECTOR GENERAL	**19.6**	**20.0**	**22.0**	**22.7**	**23.6**	**24.5**	**25.4**
TOTAL	**13,653.0**	**13,600.8**	**14,035.3**	**14,465.4**	**14,769.2**	**15,305.4**	**15,570.3**

*FY 2000 INCLUDES RESCISSION AND SUPPLEMENTAL/TRANSFER OF 20.2M FROM HSF TO MS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The Human Space Flight program is an integral component of NASA's Human Exploration and Development of Space (HEDS) Enterprise, which has as its ultimate mission to open the space frontier by exploring, using and enabling the development of space. Our current programs provide safe, assured transportation to and from space for people and payloads, and develop and operate habitable space facilities in order to enhance scientific knowledge, support technology development, and enable commercial activity. The five major goals of the HEDS Enterprise and the Human Space Flight program are the following:

- Expand the Frontier
- Expand Scientific Knowledge
- Enable and establish permanent and productive human presence in Earth orbit
- Expand commercial development of Space
- Share the experience and discovery of Human Space Flight

STRATEGY FOR ACHIEVING GOALS

In Human Space Flight, we are committed to ensuring effective, efficient and safe transportation to and from space. Our first priority is to fly safely. This requires constant vigilance from the entire Shuttle community, as well as making appropriate investments to reduce risks and increase the safety of the Space Shuttle. In addition, we are actively probing our processes in order to reduce operational costs, improve performance on development projects and to selectively enhance capabilities to meet customer needs.

As we expand our capabilities for allowing humans to live and work continuously in space, we have transitioned our research from the Shuttle-borne Spacelab, to the conduct of joint space activities with Russia aboard the Mir, and now in FY 2001 and beyond to the International Space Station.

Human Space Flight, through the utilization of Space Shuttle and Space Station, provides the capabilities to enable the advancement of scientific knowledge leading to new discoveries, technologies, and materials that will benefit future space exploration and development, as well as life on Earth. In meeting these capabilities, we will ensure that our workforce, our most important resource, will have management support to meet operational and future program requirements through career development training and employee recognition programs.

Recognizing the national benefits of past and future space activities, we will work diligently to maximize the Human Space Flight program's contribution to the national community. These contributions will be implemented by contributing to science and engineering educational opportunities for our youth, and in space through support of collaborative relationships with industry and by improving the nation's quality of life by making advanced technology, directly and through "spinoffs", available to the private sector.

Human space flight achievements in exploration and development of space have paved the way for enhancing our nation's leadership in expanding the human presence in space. The necessity to fly safely and the requirement to satisfy payload customer needs, while striving to reduce operations costs will be the dominant programmatic thrusts throughout the next decade. Our success in achieving Human Space Flight goals and objectives will play a central role in leading our Nation towards realizing the boundless potential for humankind, of the exploration and development of space.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
HUMAN SPACE FLIGHT	**5,480.0**	**5,510.9**	**5499.9**
SPACE STATION	2,299.7	2,323.1	2,114.5
SPACE SHUTTLE	2,998.3	2,979.5	3,165.7
PAYLOAD UTILIZATION AND OPERATIONS	182.0	165.1	--
PAYLOAD AND ELV SUPPORT	--	--	90.2
INVESTMENTS AND SUPPORT	--	--	129.5

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

HUMAN SPACE FLIGHT

For necessary expenses, not otherwise provided for, in the conduct and support of human space flight research and development activities, including research, development, operations, and services; maintenance; construction of facilities including [repair, rehabilitation,] *revitalization* and modification of [real and personal property] *facilities, construction of new facilities and additions to existing facilities, facility planning and design*, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,510,900,000] $5,499,900,000, to remain available until September *30, [2001: Provided,* That $40,000,000 of the amount provided in this paragraph shall be available to the space shuttle program only for preparations necessary to carry out a life and micro-gravity science mission, to be flown between STS-107 and December 2001] *2002. For necessary expenses of the International Space Station, to become available on October 1 of the fiscal year specified and remain available for that and the following fiscal year, as follows: for fiscal year 2002, $1,858,500,000, for fiscal year 2003, $ 1,452,500,000, for fiscal year 2004, $1,327,000,000; and for fiscal year 2005, $1,275,000,000. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUMAN SPACE FLIGHT

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
HUMAN SPACE FLIGHT	**183.0**	**203.6**	**195.2**
SPACE STATION	--	.1	.1
SPACE SHUTTLE	42.2	24.9	13.3
PAYLOAD UTILIZATION AND OPERATIONS	140.8	178.6	--
PAYLOAD AND ELV SUPPORT	--	--	1.2
INVESTMENTS AND SUPPORT	--	--	180.6

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 ESTIMATES

DISTRIBUTION OF HUMAN SPACE FLIGHT BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Space Station	1999	2,299,700	1,868,900	114,300	221,000	0	42,000	0	5,100	40,500	900	5,400	1,600
	2000	2,323,100	1,710,100	113,300	391,200	0	47,100	2,500	800	40,700	300	12,100	5,000
	2001	2,114,500	1,512,100	92,900	327,000	0	77,900	6,000	4,100	75,000	0	14,500	5,000
Space Shuttle	1999	2,998,300	1,721,400	173,300	1,050,500	38,100	3,500	4,600	200	200	2,300	300	3,900
	2000	2,979,500	1,658,900	185,800	1,079,900	40,300	4,500	4,800	0	200	100	0	5,000
	2001	3,165,700	1,768,100	222,600	1,131,900	30,000	3,000	4,800	0	200	100	0	5,000
Payload and Utilization Operations	1999	182,000	44,261	66,765	51,039	1,650	300	0	1,885	450	15,000	500	150
	2000	165,100	20,731	79,068	43,600	1,600	0	0	0	0	8,900	35	11,166
	2001	0	0	0	0	0	0	0	0	0	0	0	0
Paylaod and ELV Support	1999	0	0	0	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0	0	0	0
	2001	90,200	1,300	77,600	1,100	0	0	0	0	0	10,200	0	0
Investments and Support	1999	0	0	0	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0	0	0	0
	2001	129,500	30,800	12,800	37,800	23,300	0	0	0	0	0	0	24,800
TOTAL HUMAN SPACE FLIGHT	1999	5,480,000	3,634,561	354,365	1,322,539	39,750	45,800	4,600	7,185	41,150	18,200	6,200	5,650
	2000	5,467,700	3,389,731	378,168	1,514,700	41,900	51,600	7,300	800	40,900	9,300	12,135	21,166
	2001	5,499,900	3,312,300	405,900	1,497,800	53,300	80,900	10,800	4,100	75,200	10,300	14,500	34,800

INTERNATIONAL SPACE STATION

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **SPACE STATION**

SUMMARY OF RESOURCES REQUIREMENTS*

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Vehicle	1,183,900	890,100	442,600	HSF 1-6
Operations Capability	576,300	763,600	826,500	HSF 1-18
[Construction of Facilities included]	[1,200]	[--]	[--]	
Research	336,500	394,400	455,400	HSF 1-27
Russian Program Assurance	203,000	200,000	300,000	HSF 1-40
Crew Return Vehicle	--	75,000	90,000	HSF 1-45
Total	2,299,700	2,323,100	2,114,500	
Distribution of Program Amount by Installation				
Johnson Space Center	1,868,900	1,710,100	1,512,100	
Kennedy Space Center	114,300	113,300	92,900	
Marshall Space Flight Center	221,000	391,200	327,000	
Ames Research Center	42,000	47,100	77,900	
Langley Research Center	5,100	800	4,100	
Glenn Research Center	40,500	40,700	75,000	
Goddard Space Flight Center	900	300		
Dryden Flight Research Center		2,500	6,000	
Jet Propulsion Laboratory	5,400	12,100	14,500	
Headquarters	1,600	5,000	5,000	
Total	2,299,700	2,323,100	2,114,500	

* Summary adjusted to reflect the effect of restructured budget in FY 2000, and prospective reallocations to the FY 1999 operating plan, and to the FY 2000 operating plan. The December 23, 1999 operating plan for FY 1999, and this estimate, includes $203 million for Russian Program Assurance (RPA). NASA has not submitted to Congress the intended increase of $100 million for RPA for Operating Plan consideration, pending further discussions with Rosaviakosmos, the Russian Aeronautics and Space Agency. This budget also assumes an additional reduction in FY 2000 of $11.5 million from Operations in order to implement the 0.38% rescission enacted, and a reallocation of $21 million from Operations to maintain the Phase 1 development for the Crew Return Vehicle (see special section "FY 2000 Changes").

PROGRAM GOALS

The goal of the International Space Station (ISS) is to establish a long-duration habitable residence and laboratory for science and research and permanently deploy a crew to this facility. The ISS will vastly expand the human experience in living and working in space, encourage and enable commercial development of space, and provide a capability to perform unique, long duration, space-based research in cell and developmental biology, plant biology, human physiology, fluid physics, combustion science, materials science and fundamental physics. ISS will also provide a unique platform for making observations of the Earth's surface and atmosphere, the sun, and other astronomical objects. The experience and dramatic results obtained from the use of the ISS will guide the future direction of the Human Exploration and Development of Space Enterprise, one of NASA's key strategic areas. The International Space Station is critical to NASA's ability to fulfill its mission to explore, use, and enable the development of space for human enterprise.

STRATEGY FOR ACHIEVING GOALS

The ISS is a laboratory in low Earth orbit on which American and international crews will conduct unique scientific and technological investigations in a microgravity environment. Establishing a permanent human presence in space, which the ISS makes possible, remains one of NASA's highest priorities. The Space Station is unique because it will provide the world with an unparalleled laboratory and habitable international outpost in space. The schedule for the current design emphasizes an early permanent crew capability that provides an advanced research facility for use by international crews for extended duration missions. Therefore, early in the on-orbit assembly of the program, the Space Station will provide the capability to stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to the storehouse of scientific knowledge.

The baseline program content includes ISS vehicle development, operations capability, research, and has been expanded to enable the development of a U.S. crew return capability, and a number of contingency activities provided within Russian Program Assurance. Extensive coordination with the user community is well underway, and payload facilities development and research and technology activities are coordinated with the Office of Life and Microgravity Sciences and Applications (OLMSA), the Office of Earth Science (OES) and the Office of Space Science (OSS). OLMSA has administrative responsibility for the ISS Research program starting in FY 2000.

The ISS represents an unprecedented level of international cooperation. Space Station Partnership agencies include NASA, the Russian Aviation and Space Agency (Rosaviakosmos), the Canadian Space Agency (CSA), the European Space Agency (ESA), and the National Space Development Agency of Japan (NASDA). International participation in the program has significantly enhanced the capabilities of the ISS.

Russian contributions to the ISS include the Service Module, universal docking module, science power platform, docking compartment, life support module, and research modules. The Service Module will provide early sleeping and living quarters for crew members. Russia will also provide logistics resupply and station reboosting capability with the Progress and other vehicles, as well as crew transfers aboard the Soyuz vehicle. Russian participation in the space station is significant, providing for a more capable research laboratory, able to sustain a larger crew of researchers than would have been possible without them. They contribute the Soyuz crew module. This makes it possible to place crews aboard to conduct research during the assembly sequence, instead of having to wait until the station is completed and a U.S. crew return capability is available. They also provide Progress supply transports, which provide a great deal of the resupply needs, both during assembly and during ten years of operations.

Canada's contribution to the ISS is the Mobile Servicing System (MSS) and its associated ground elements. The MSS will provide a second-generation robotic arm similar to the Canadian arm developed for the Shuttle. The MSS consists of the 58-foot long Space Station Remote Manipulator System (SSRMS) that can handle masses up to 220,000 pounds, a Base System, and a 12-foot robotic arm called the Special Purpose Dexterous Manipulator (SPDM) that attaches to the SSRMS. CSA has developed a Space Operations Support Centre, MSS Simulation Facility and Canadian MSS Training Facility. CSA's Space Station utilization allocation is 2.7%.

The National Space Development Agency of Japan (NASDA) will provide the Japanese Experiment Module (JEM), which consists of a number of different components. Those components include the following elements: a Pressurized Module (PM), a pressurized laboratory that provides 77% of the utilization capability of the U.S. laboratory and can accommodate 10 racks; an Exposed Facility (EF) for up to 10 unpressurized experiments; a 32-foot robotic arm used for servicing system components on EF and changing out attached payloads; and an Experiment Logistic Module (ELM) for both pressurized and unpressurized logistics resupply, and the HII Transfer Vehicle (HTV) for ISS logistics resupply.

European Space Agency (ESA) contributions emphasize their role in early and continued utilization of the ISS and augmenting the ISS infrastructure. The ESA contributions include: the Columbus Orbital Facility (COF) with accommodations for 10 standard racks; the Automated Transfer Vehicle (ATV) for ISS logistics resupply, propellant resupply and reboost missions, to be launched by the Ariane 5 launch vehicle: and cooperation on the X-38, which is the protoflight vehicle for the ISS Crew Return Vehicle (CRV). ESA will also participate on the CRV as well. ESA has also made separate arrangement with the Russian Aviation and Space Agency for two contributions to the Russian elements: the European Robotic Arm (ERA) on the Russian Science and Power Platform and the Data Management System (DMSR) for the Service Module.

Additionally, there are several bilateral agreements between NASA and other nations such as Italy and Brazil, resulting in a total number of fifteen U.S. international partners. An agreement with ESA provides early research opportunities to them in exchange for provision of research equipment to the U.S. Another agreement with ESA provides the U.S. with Nodes 2 and 3 as an offset for the Shuttle launch for the Columbus Orbital Facility (COF). A similar Agreement in Principle with NASDA provides a Centrifuge,

Centrifuge Accommodation Module (CAM), and Life Sciences Glovebox as an offset for the Shuttle launch of the Japanese Experiment Module (JEM). NASA and the Italian Space Agency have an agreement for Italy's provision of three Multi-Purpose Logistics Modules (MPLMs) in exchange for research opportunities. The Brazilian Space Agency (AEB) has become a participant in the U.S. ISS program by helping fulfill a portion of U.S. obligations to the ISS program in exchange for access to the U.S. share of ISS resources.

Through FY 1999, the ISS cooperative international agencies, excluding Russia, had invested over $5 billion dollars in design and development activities, of a total estimated investment expenditure of approximately $9 billion. Because Russia's transition to a free market economy is still underway, it is not possible to accurately project their financial investment. However, their hardware contribution is approximately a third of the mass of the completed assembly of the ISS and will provide nearly half of the pressurized volume of the ISS.

Development of the Space Station program is being conducted in a phased approach. The initial phase, which was successfully concluded in 1998, included nine Shuttle-Mir docking missions. The goals of the initial phase, which were successfully accomplished, were to develop and demonstrate joint mission procedures with Russia, gain valuable experience to reduce technical risk during International Space Station construction, and provide early opportunities for extended scientific research.

The next phase of the program began with the launch of the U.S.-owned/Russian-launched Zarya propulsion module in November 1998, which was soon followed by the Shuttle deployment of the U.S. Unity module in December of 1998. Since then, most ISS on-orbit systems have been performing above expectations, with few anomalies. The transition of U.S. and Russian space station operations leadership, from Russia during Shuttle-Mir, to the U.S. lead responsibility for the ISS stack has been carried out exceptionally well. This phase, which concludes with the launch of the airlock on flight 7A, will establish the initial research capability for ISS. The initial crew of three persons is scheduled to be deployed in mid-FY 2000, with the launch of the first Russian Soyuz spacecraft to ISS. From that point forward, a U.S. citizen will permanently reside on the ISS beyond the confines of earth. Microgravity capability will be available in late FY 2000, with the outfitting of the U.S. laboratory. At completion of this phase in late-FY 2000, the Station configuration will include Unity (the first U.S. node), Destiny (the U.S. laboratory), pressurized mating adapters, power, airlock, multi-purpose logistics module (MPLM); Zarya, the Russian service module, a Soyuz capsule, and the Space Station remote manipulator system (SSRMS) provided by Canada.

The fundamental nature of living and working in the isolated realm of space will change dramatically as the Program moves into and through the last phase of the program, which will see completion of assembly in the 2005 timeframe. During this period, the number of crew on orbit will increase to six members, with an associated increase in crew time for research. The number of payload research racks will increase from 3 to 38 racks, with experiment power availability for payloads increasing from 10 watts to over 40 watts. By the end of FY 2002 the Station configuration will include the U.S. Laboratory, truss segments, three solar arrays, and resupply/support vehicles. By the end of FY 2003, the second U.S. node, the Japanese Experiment Module (JEM), the Japanese Logistics Module (JLM), and the U.S. propulsion module are to be deployed, as well as the Science Power Platform (SPP). By the end of FY 2004 the Station configuration will include the Columbus Orbital Facility (COF, ESA's pressurized module), the Japanese Exposed Facility (JEF), a Russian research module, the Russian Docking and Stowage Module (DSM), the third U.S. Node, and the Cupola. A flight to outfit the third U.S. node will mark the beginning of the permanent 6-member crew capability. Delivery of the

fourth solar array, the Centrifuge Accommodation Module, and the habitation module in FY 2005 will signal the initiation of the permanent 7-member crew capability. Implementation of these permanent crew capabilities will be dependent on adequate crew return capabilities. Routine logistics module launches to the Space Station will continue over the remaining life of the Station.

Due to the late October 1999 Proton failure and the extended duration of the resulting investigation, the launch schedule for FY 2000 and subsequent years remains somewhat uncertain. While the next ISS launch, the Russian Service Module, is on a path to resolve remaining test anomalies early in 2000, the actual schedule launch will likely be dependent on recommendations resulting from the Proton investigative teams. This will result in at least a four month delay from the current baselined assembly sequence, which is roughly commensurate with delays introduced from 1999 Shuttle wiring inspections and corrective action, as well as slippage in U.S. ISS integration, test and verification activities. As a contingency against a delay of the Service Module in excess of four months, the program is reviewing the possibility of flying an interim mission in mid-FY 2000, using the Shuttle to perform critical services and activities. A firm launch date for the Service Module is expected to be set following reviews in February 2000.

The approach in this budget justification is to reflect the baselined assembly sequence (Revision E) for intermediate milestones for Vehicle Development, Research, and Russian Program Assurance, reflecting the program plan to maintain development/on-dock milestones in order to mitigate contractor cost growth. Launch dates in these sections are listed for Revision E, and a second target that reflects the current assembly planning sequence (11/12/99). The intermediate milestones and launch dates in the Operations Capability section, however, have been adjusted to reflect the current assessment (11/12/99) that includes a four month slip to the Revision E assembly schedule.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE STATION VEHICLE

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Flight hardware	1,026,000	716,400	401,500
Test, manufacturing and assembly	134,500	122,900	38,700
Transportation support	23,400	50,800	2,400
Total	1,183,900	890,100	442,600

PROGRAM GOALS

Vehicle development of the International Space Station (ISS) provides an on-orbit, habitable laboratory for science and research activities, including flight and test hardware and software, flight demonstrations for risk mitigation, facility construction, Shuttle hardware and integration for assembly and operation of the station, mission planning, and integration of Space Station systems.

STRATEGY FOR ACHIEVING GOALS

Responsibility for providing Space Station elements is shared among the U.S. and our international partners from Russia, Europe, Japan, and Canada. The U.S. elements include three nodes, a laboratory module, airlock, truss segments, four photovoltaic arrays, a habitation module, three pressurized mating adapters, unpressurized logistics carriers, and a cupola. Various systems are also being developed by the U.S., including thermal control, life support, navigation and propulsion, command and data handling, power systems, and internal audio/video. The U.S. funded elements also include the Zarya propulsion module provided by a Russian firm under the Boeing prime contract. Other U.S. elements being provided through bilateral agreements include the pressurized logistics modules provided by the Italian Space Agency, Nodes 2 and 3 provided by ESA, and the centrifuge accommodation module (CAM) and centrifuge provided by the Japanese.

Canada, member states of the European Space Agency (ESA), Japan, and Russia are also responsible for providing a number of ISS elements. The Japanese, ESA, and Russia will provide laboratory modules. Canada will provide a remote manipulator system, vital for assembly and maintenance of the station. The Russian Aviation and Space Agency (Rosaviakosmos) is also providing significant ISS infrastructure elements including the Service Module (SM), science power platform, Soyuz crew transfer vehicle, Progress resupply vehicles, and universal docking modules.

The Boeing Company is the prime contractor for the design and development of U.S. elements of the International Space Station. It also has prime responsibility for integration of all U.S. and International Partner contributions and for assembly of the ISS. At their Huntington Beach site location (formerly McDonnell Douglas), Boeing is developing and building the integrated truss segments that support station elements and house essential systems, including central power distribution, thermal distribution, and attitude control equipment. Other Boeing locations are also supporting the flight hardware build to mitigate capability shortfalls at Huntington Beach. Additionally, major components of the communications and data handling, thermal control, and the guidance, navigation and control subsystems are being developed at Huntington Beach.

U.S. pressurized modules are being developed by Boeing at their Huntsville site location, and by ESA and Japan. The second flight to ISS, successfully conducted in December 1998, deployed Unity, a pressurized node which contains four radial and two axial berthing ports. Attached to the Node were two pressurized mating adapters (PMAs), which serve as docking locations for the delivery of the U.S. Laboratory Module and the Multi-Purpose Pressurized Logistics Module. Under a bilateral agreement, ESA is providing Nodes 2 and 3 and a cupola to the U.S. Node 2 is currently manifested for flight during the first quarter of FY 2003, the Cupola is manifested for flight during the second quarter of FY 2004, and Node 3 is manifested for flight during the third quarter of FY 2004. The final U.S. pressurized volume is the Habitation Module that will contain the galley, wardroom, waste management, water processing and other crew support functions necessary for human operations.

The power truss segments and power system, essential to the Station's housekeeping operations and scientific payloads, are being built by Boeing at their Canoga Park location (formerly Rocketdyne Division, Rockwell International). Four photovoltaic elements, each containing a mast, rotary joint, radiator, arrays, and associated power storage and conditioning elements, comprise the power system.

The vehicle program also includes test, manufacturing and assembly support for critical NASA center activities and institutional support. These "in-line" products and services include: test capabilities; the provision of government-furnished equipment (GFE), including flight crew systems, environment control and life support systems, communications and tracking, and extravehicular activity (EVA) equipment; and engineering analyses. As such, they support the work of the prime contractor, its major subcontractors and NASA system engineering and integration efforts.

Transportation support provides those activities that allow the Space Shuttle to dock with the Space Station. This budget funded the development and procurement of two external Shuttle airlocks, and upgrade of a third airlock to full system capability, which were required for docking the Space Shuttle with the Russian Mir as well as for use with the Space Station. Other items in this budget include: the Shuttle Remote Manipulator System (RMS) and Space Shuttle mission training facility upgrades; development of a UHF communications system and a laser sensor; procurement of an operational space vision system; procurement of three docking mechanisms and Space Station docking rings; EVA/Extravehicular Mobility Units (EMU) services and hardware; and integration costs to provide analyses and model development.

SCHEDULE & OUTPUTS

Completed Incremental Design Review (IDR)
Performed Stage Integration Reviews (SIR)

A series of incremental, cumulative reviews throughout the design phase to assure that system level requirements are properly implemented in the design, have traceability, and that hardware and software can be integrated to support staged assembly and operation. IDR #1 performed these functions for flights 1A/R through 6A. Subsequently, IDR #2 assessed design progress for flights 1A/R through 7A. IDR#2B assessed the entire Space Station assembly sequence.

IDRs have been replaced by Stage Integration Reviews (SIR), a more classical critical design review approach on a stage-by-stage basis which review groupings of flights with assembly hardware and functionality/performance linkages across the stage.

- Performed SIR 1 for flights through 2A (4th Qtr FY 1997)
- Performed SIR 2 for flights through 4A (1st Qtr FY 1998)
- Performed SIR 3 for flights through 6A (2nd Qtr FY 1998)
- Performed SIR 4 for flights through 4R (1st Qtr FY 1999)
- Performed SIR 5 for flights through UF-2 (1st Qtr FY 2000)
- Perform SIR 6 for flights through 9A.1 (2nd Qtr FY 2000)
- Perform SIR 7 for flights through 13A (4th Qtr FY 2000)
- Perform SIR 8 for flights through 10A.1 (2nd Qtr FY 2001)
- Perform SIR 9 for flights through UF3 (3rd Qtr FY 2001)

Prime Development Activity

NOTE: All activities listed are planning milestones, and are not contractual.

Flight 1A/R:
Zarya (FGB Energy Block)
(First Element Launch)
(Proton Launch Vehicle)
Planned (Rev B): Nov. 1997
Revised (Rev D Mod): Nov.1998
Completed November 1998

Self-powered, active vehicle; provides attitude control through early assembly stages; provides fuel storage capability after the service module is attached; provides rendezvous and docking capability.

- Completed factory ground testing of first flight unit (slip from 3rd Qtr FY 1997 to 2nd Qtr FY 1998)
- Completed flight software (slip from 3rd Qtr FY 1997 to 1st Qtr FY1998)
- Delivered FGB flight article to Baikanour (slip from 3rd Qtr FY 1997 to 2nd Qtr FY 1998)
- Installed solar arrays in FGB flight article (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998)
- Removed Zarya from storage and complete deconservation (1st Qtr FY 1999)
- Mated FGB to Launch Vehicle (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999)
- On-Orbit checkout, Service Module docking, fuel transfer (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999)
- Launch of the Zarya (1st Qtr FY 1999)

Flight 2A: Unity (Node 1), Pressurized Mating Adapters (PMA-1, PMA-2) Planned (Rev B): Dec. 1997 Revised (Rev D Mod): Dec. 1998 Completed December 1998	Initial U.S. pressurized element, launched with PMA-1, PMA-2, and 1 stowage rack; PMA-1 provides the interfaces between U.S. and Russian elements; PMA-2 provides a Space Shuttle docking location. • Completed Node STA static flight loads testing (slip from 4th Qtr FY 1997 to 1st Qtr FY 1998) • Completed mating of PMA-1 to Node (1st Qtr FY 1998) • Completed flight 2A Cargo Element Integration and Test (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998) • Completed mating of PMA-2 to Node (3rd Qtr FY 1998) • Space Shuttle Payload Integration and Test (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999) • Launch of Unity (flight 2A) (1st Qtr FY 1999)
Flight 2A.1 Logistics Planned (Rev C): Dec. 1998 Revised (Rev D Mod): 3rd Qtr FY 1999 Completed June 1999	Double Spacehab flight for logistics/resupply during early assembly; • Station Cargo Integration Review (SCIR) (2nd Qtr FY 1998) • Flight Operations Review (FOR) (2nd Qtr FY 1999) • Hardware on dock at KSC (2nd Qtr FY 1999) • Begin integration of critical spares into Spacehab Module (2nd Qtr FY 1999) • Delivery of Strela Cargo Crane to Integrated Cargo Carrier integration (2nd Qtr FY 1999) • Launch of flight 2A.1 (3rd Qtr FY 1999)
Flight 2A.2 Logistics Planned: 4th Qtr FY 1999 Revised (Rev E): 1st Qtr FY 2000 Revised Target: 3rd Qtr FY 2000	Double Spacehab flight for logistics/resupply during early assembly. Also delivers Crew Health Care Systems hardware with which to outfit the service module • Delivery of TVIS for integration into Spacehab (4th Qtr FY 1999) • Delivery of Strela Crane and components (1st Qtr FY 2000) • Spacehab turnover to KSC (1st Qtr FY 2000) • ICC Hardware Integration (1st Qtr FY 2000) • Launch Flight 2A.2 (3rd Qtr FY 2000)

Flight 3A:
Z1 Truss Segment, Control Moment Gyros (CMGs), PMA-3, KU-Band
Planned (Rev B): July 1998
Revised (Rev D Mod): 1st Qtr FY 2000
Revised (Rev E): 2nd Qtr FY 2000
Revised Target: 3rd Qtr FY 2000

Z1 Truss allows temporary installation of the P6 photovoltaic module to Node 1 for early U.S. based power; KU-band and CMGs support early science capability; PMA-3 provides a Space Shuttle docking location for the lab installation on flight 5A.

- Completed CMG qualification and flight testing (2nd Qtr FY 1998)
- Z1 modal and static qualification tests complete (slip from 4th Qtr FY 1997 to 2nd Qtr FY 1998)
- PMA-3 on-dock at KSC (Slip from 4th Qtr FY 1997 to 2nd Qtr FY 1998)
- KU-Band antenna on dock at KSC (3rd Qtr FY 1998)
- S-Band antenna on dock at KSC (3rd Qtr FY 1998)
- Z1 flight unit completed and shipped to KSC (3rd Qtr FY 1998)
- Plasma Contactor and DDCU-HP Qualification Testing complete (4th Qtr FY1999)
- 3A MEIT complete (2nd Qtr FY 2000)
- Complete Z1 final outfitting (2nd Qtr FY 2000)
- Launch of flight 3A (3rd Qtr FY 2000)

Flight 4A:
P6 Truss segment, Photovoltaic Array, Thermal Control System (TCS) Radiators, S-Band Equipment
Planned (Rev B): Nov. 1998
Revised (Rev D Mod): 1st Qtr FY 2000
Revised (Rev E): 2nd Qtr FY 2000
Revised Target: 4th Qtr FY 2000

This flight provides the first U.S. solar power via solar arrays and batteries, cooling capability and S-Band system activation

- Beta Gimbal Assembly to P6 Integration (3rd Qtr FY 1998)
- IEA/Long Spacer ready for integration and test (4th Qtr FY 1998)
- Z1/P6 on dock KSC for MEIT (4th Qtr FY 1998)
- Radiator Qualification Testing complete (2nd Qtr FY 1999)
- Solar Arrays on-dock KSC (2nd Qtr FY 1999)
- Flight Radiators delivered to P6 Outfitting (1st Qtr FY 2000)
- 4A MEIT complete (2nd Qtr FY 2000)
- Launch flight 4A (4th Qtr FY 2000)

Flight 5A:
U.S. Laboratory, 5 Lab System Racks
Planned (Rev B): Dec. 1998
Revised (Rev D Mod): 2nd Qtr FY 2000
Revised (Rev E): 3rd Qtr FY 2000
Revised Target: 4th Qtr FY 2000

Launch of the U.S. Laboratory Module establishes initial U.S. user capability; launches with 5 system racks pre-integrated; KU-band and CMGs are activated.

- Complete installation of 5A/6A Racks in Lab for testing (3rd Qtr FY 1998)
- Lab on dock at KSC (1st Qtr FY 1999)
- Lab Acceptance Testing Complete (1st Qtr FY 2000)
- Deliver Command and Control and Guidance Navigation and Control Software to Lab (1st Qtr FY 2000)
- Complete 5A MEIT (2nd Qtr FY 2000)
- Launch of flight 5A (4th Qtr FY 2000)

Flight 5A.1: MPLM flight module-1, 6 Lab System Racks, 1 Payload Rack Planned: 2nd Qtr FY 2000 Revised (Rev E): 3rd Qtr FY 2000 Revised Target: 1st Qtr FY 2001	Continues the outfitting of the U.S. Lab, with the launch of 6 system racks. This flight also represents the first use of science with the launch of the Human Research Facility (HRF) rack. It is also the first use of the Multi-Purpose Logistics Module (MPLM). • Complete MPLM Integration and Test (4th Qtr FY 1998) • MPLM on-dock at KSC (4th Qtr FY 1998) • Integration of HRF Sub-racks into the HRF rack (4th Qtr FY 1999) • HRF rack on-dock at KSC (2nd Qtr FY 2000) • Early Ammonia Servicer On-Dock KSC (2nd Qtr FY 2000) • MPLM Rack Installation/Closeout (3rd Qtr FY 2000) • Launch of 5A.1 (1st Qtr FY 2001)
Flight 6A: MPLM flight module-2, Canadian Remote Manipulator System, UHF Planned (Rev B): January 1999 Revised (Rev D Mod): 3rd Qtr FY 2000 Revised (Rev E): 4th Qtr FY 2000 Revised Target: 1st Qtr FY 2001	Continues U.S. lab outfitting with delivery of 2 stowage and 2 EXPRESS payload racks; UHF antenna provides space-to-space communication capability for U.S. based EVA; delivers Canadian SSRMS needed to perform assembly operations of later flights. • SSRMS On-dock KSC (3rd Qtr FY 1999) • Complete Integration and Test of MPLM FM2 (4th Qtr FY 1999) • MPLM FM2 On-dock KSC (4th Qtr 1999) • SSRMS and RWS Software complete (2nd Qtr FY 2000) • 6A MEIT Complete (2nd Qtr FY 2000) • MPLM Rack Integration / Closeout (3rd Qtr FY 2000) • Launch of flight 6A (1st Qtr FY 2001)
Flight 7A: Airlock, HP Gas Plan (Rev B): April 1999 Revised (Rev D Mod): 4th Qtr FY 2000 Revised (Rev E): 4th Qtr FY 2000 Revised Target: 2nd Qtr FY 2001	Launches the airlock and installs it on orbit. The addition of the airlock permits ISS-based EVA to be performed without loss of environmental consumables such as air. • Completed Airlock Integration/A&CO (2nd Qtr FY 1999) • Airlock System Software Complete (2nd Qtr FY1999) • Element level testing complete (1st Qtr FY 2000) • Airlock on dock at KSC (1st Qtr FY 2000) • Complete SLP integration (2nd Qtr FY 2000) • Launch flight 7A (2nd Qtr FY 2001)

Flight 7A.1 MPLM, SLP pallet Planned (Rev B): Nov. 1999 Revised (Rev D Mod): 4th Qtr FY 2000 Revised (Rev E): 1st Qtr FY 2001 Revised Target: 2nd Qtr FY 2001	Logistics and utilization mission delivering resupply/return stowage racks resupply stowage platforms, and two EXPRESS payload racks. This flight will carry critical spares as well as various resupply items. • Hardware and schedule for this flight is currently undergoing replanning.
Flight 8A: S0 Truss, Mobile Transporter, Plan (Rev B): June 1999 Revised (Rev D Mod): 2nd Qtr FY 2001 Revised (Rev E): 2nd Qtr FY 2001 Revised Target: 3rd Qtr FY 2001	S0 is the truss segment that provides attachment and umbilicals between pressurized elements and truss mounted distributed systems/utilities. Mobile Transporter provides SSRMS translation capability along the truss. • Complete S0 flight fabrication, assembly, and outfitting (3rd Qtr FY 1999) • S0 on dock at KSC (3rd Qtr FY 1999) • Complete S0 STA Testing (4th Qtr FY 1999) • Complete Mobile Transporter flight article (4th Qtr FY 1999) • Command and Control Software Complete (3rd Qtr FY 2000) • 8A MEIT Complete (1st Qtr FY 2001) • Launch flight 8A (3rd Qtr FY 2001)
Flight 9A: S1 Truss, CETA Cart Plan (Rev B): September 1999 Revised (Rev D Mod): 3rd Qtr 2001 Revised (Rev E): 4th Qtr FY 2001 Revised Target: 1st Qtr FY 2002	S1 truss provides permanent active thermal control capability. Crew and Equipment Translation Aid (CETA) cart provides EVA crew translation capability along the truss. • Complete second S-band string (4th Qtr FY 1998) • Radiators complete for S1 Integration (2nd Qtr FY 2000) • Complete S1 STA testing (2nd Qtr FY 2000) • Complete S1 flight Outfitting and Acceptance Testing (2nd Qtr FY 2000) • S1 on dock at KSC (1st Qtr FY 2000) • 9A MEIT Complete (1st Qtr FY 2000) • Launch flight 9A (1st Qtr FY 2002)

Flight 11A: P1 Truss (3 Radiators), TCS, CETA, and UHF Band Communications Plan (Rev B): January 2000 Revised (Rev C): 1st Qtr FY 2001 Revised (Rev E): 4th Qtr FY 2001 Revised Target: 2nd Qtr FY 2002	P1 truss provides permanent active thermal control capability. Crew and Equipment Translation Aid (CETA) cart provides EVA crew translation capability along the truss. • Radiators complete for P1 Integration (2nd Qtr FY 2000) • P1 on dock at KSC (2nd Qtr FY 2000) • Complete P1 flight Acceptance Testing (3rd Qtr FY 2000) • CETA Cart Ready for P1 Integration (3rd Qtr FY 2000) • Pump Module ready for P1 Integration (3rd Qtr FY 2000) • 11A MEIT Complete (1st Qtr FY 2001) • Launch flight 11A (2nd Qtr FY 2002)

Non-Prime Development Activity

Global Positioning System (GPS)	Provides autonomous, real-time determination of Space Station's position, velocity, and attitude. • Delivered GPS Antenna Assembly (4th Qtr FY 1997) • Delivered GPS Receiver/Processor (slip from 3rd Qtr FY 1997 to 2nd Qtr FY 1999)
Extra-Vehicular Activity System	Provides Government Furnished Equipment (GFE), EVA unique tools, and EVA support equipment for the Space Station. Provides EVA development and verification testing. Provides for operation of the WETF/NBL and the maintenance of neutral buoyancy mockups to support Station EVA development activities. • Delivered Crew Equipment Transfer Aid (CETA) Cart proto-flight unit (slip from 1st Qtr FY 1997 to 1st Qtr FY2000) • Delivered EVA Tool Storage Device (ETSD) for CETA Cart (1st Qtr FY 1998) • Delivered ETSD for airlock (1st Qtr FY 1998) • Delivered canisters for the Regenerable CO_2 System (3rd Qtr FY 1998) • Delivered 1st Flight Regenerator for the Regenerable CO_2 System (3rd Qtr FY 1998) • ORU Transfer Device (OTD) flight unit delivered (1st Qtr FY 1999)
Flight Crew Systems	Provides flight and training hardware and provisions for food and food packaging development; housekeeping management; portable breathing apparatus; restraints and mobility aids; tools, diagnostic equipment and portable illumination kit. • Completed 6A Operations and Personal Equipment CDR (1st Qtr FY 1997)

- Delivered Restraints and Mobility Aids (1st Qtr FY 1997)
- Completed CDR for portable illumination (2nd Qtr FY 1997)
- Completed production of tools and diagnostic flight hardware kit (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998)
- Completed Personal Hygiene Kit PRR Preliminary/Program Requirements Review (2nd Qtr FY 1998)
- Delivered Maintenance Workstation Kit, Portable Illumination, and Housekeeping Kit (4th Qtr FY 1998)

Airlock Service And Performance Checkout Unit	Provides flight servicing, performance unit, and certification unit, Russian space suit support hardware interface definition and documentation, test plans and reports, mockups, and thermal analysis.

- Delivered Qual hardware to airlock test article (Slip from 2nd Qtr FY 1997 to 2nd Qtr FY 1999)
- Final Flight Unit Deliveries (2nd Qtr FY 2000)

ACCOMPLISHMENTS AND PLANS

FY 1999 activities focused on the buildup of ISS elements required for Phase 2/3 assembly of the International Space Station. These activities included:

- Modifications to the Zarya spacecraft, implemented under the U.S. Russian Cooperation and Program Assurance budget to accommodate SM uncertainties, have been completed. Testing on the Zarya was completed in May 1998, and it was in storage at the Baikonur launch site until August. The Zarya launched November 20th, 1998.

- The flight 2A activities in FY 1998 included Common Berthing Module acceptance testing, Cargo Element integration, and the completion of Space Station Processing Facility integration. Flight 2A launched December 4th, 1998.

- Flight 2A.1 was added to the assembly sequence in early FY 1998. Two elements, a Spacehab double module and an ICC (Integrated Cargo Carrier) for the Russian Strela (cargo crane) are required to transport certain Spares and supplies, and to enable EVA operations. Flight 2A.1 was launched on May 27, 1999.

- Flight 2A.2 was added to the assembly sequence in early FY 1999. This flight carries the same two elements, a Spacehab double module and an ICC, as flight 2A.1. The cargo to be flown includes internal and external spares and supplies, as well as station outfitting equipment.

- In preparation for flight 3A, Z1/P6 integrated testing was completed in the 4th quarter of FY 1998. The Z1 truss segment has completed the first phase of Multi-Element Integrated Testing (MEIT) in January 1999; the final phase was completed in the third quarter of FY 1999. Final flight software verification will be completed in the 1st quarter of FY 2000, and launch package integration should begin early in the 2nd quarter of FY 2000.

- Flight 4A launches the Integrated Equipment Assembly (IEA), Photovoltaic (PV) Array, Early External Active Thermal Control System (EEATCS), and the P6 truss segment. This flight provides the first U.S. solar power via solar arrays and batteries, cooling capability and S-Band system activation. The first phase of P6 MEIT was completed in January 1999, and the final phase completed in the 3rd Qtr of FY 1999. Integrated flight software verification commenced in July 1999, and is scheduled for completion early in the 1st quarter of FY 2000.

- Flight 5A, U.S. Lab MEIT continues and is scheduled to be completed in the second quarter of FY 2000. Flight 5A/5A.1 racks have been installed, and remaining Lab testing at KSC is scheduled to be completed in the third quarter of FY 2000.

- Flight 5A.1 was added to the assembly sequence in early FY 1999. This flight represents the first use of the Multi-Purpose Logistics Module (MPLM). The MPLM for flight 5A.1 has completed its integration and testing and has been delivered to KSC. The Human Research Facility (HRF) Rack, which represents the first utilization of the ISS for science/experiments, has completed the integration of it's Sub-racks and is scheduled to be delivered to KSC in the second quarter of FY 2000.

- The MPLM used on flight 6A is the second flight unit to be built. The structure for this unit was completed early in FY 1999, and the completed unit was delivered to KSC in August of 1999. The SSRMS, which also flies on flight 6A, is scheduled to complete MEIT in the 2nd Qtr of FY 2000. There are two EXPRESS payload racks scheduled to be launched on flight 6A. One of these racks is the first use of an Active Rack Isolation System (ARIS) EXPRESS rack. Both of the EXPRESS racks are scheduled to be integrated into the MPLM in the 2nd Qtr of FY 2000.

- The airlock, which flies on flight 7A, completed its Structural Static Test in early 1998. Airlock assembly and checkout was completed in the 2nd Qtr of FY 1999. The airlock system racks were completed in FY 1998 and were integrated into the airlock for element level testing in February 1999. Delivery of the Airlock to KSC is planned for mid December 1999.

FY 2000 activities will focus on the deployment of the U.S. Laboratory, renewed development of the U.S. Habitation Module, and the start of on-orbit research with the establishment of a three-crew presence capability. All major items of flight hardware required through Flight 8A, except the Airlock, have been delivered to KSC and are undergoing various levels of integration, test, and acceptance. Specific activities for FY 2000 include:

- Flight 2A.2, planned to be launched in the 3rd quarter of FY 2000, will deliver pressurized and external logistics to aid in station assembly and to prepare for crew-tended operations.

- Flight 2R, launches a Soyuz crew transfer vehicle, providing the Space Station with three-person human permanent presence capability. This flight has been delayed pending the resolution of the Proton vehicle problems.

- Flight 3A, scheduled for the 3rd quarter of FY 2000, will deliver the Z1 truss, control moment gyros, Ku and S-Band communications equipment, EVA support equipment, and PMA-3. This will enable essential station utilities to be integrated on subsequent flights.

- Flight 4A activities in FY 2000 include the final integrated test of major sub-systems including the Early External Active Thermal Control System (EEATCS) and Photovoltaic (PV) Arrays. The launch of Flight 4A in 4th quarter of FY 2000 completes the initial power and thermal requirements for crew-tended operations.

- U.S. Lab MEIT is scheduled for completion in the 2nd quarter of FY 2000, with delta acceptance testing planned to begin in the 2nd quarter of FY 2000. The Lab launch is planned for the 4th quarter giving the ISS the capability to support initial on-orbit research. Flight 5A.1, planned for the 1st quarter of FY 2001, will outfit the lab with systems racks to support assembly phase research, using the first of three Italian-built MPLMs.

- Development of the U.S. Habitat Module has been delayed while alternative concepts were investigated. The Hab Module PDR is planned for the 2nd Qtr of FY 2001, with CDR expected in mid-FY 2002. Delivery of the Hab will support the expansion of the station crew size to 7 at Assembly Complete.

- Other major flight hardware deliveries scheduled for FY 2000 include the truss segments for flights 11A (P1), 12A (P3/P4), and 13A (S3/S4).

- Completion of 3 of the 4 Multi-Element Integrated Test (MEIT) conditions for flight elements required for assembly flights 8A through 12A.

FY 2001 will see the finish of Phase 2 and the start of Phase 3 of the ISS assembly sequence, and the beginning construction of the middle truss on the station's backbone (Z1 Truss) launched the previous year. Two Utilization Flights and one outfitting / logistics flight will enable a broader range of research to be conducted as ISS assembly continues. Activities in preparation for these flights include:

- Flight 6A will complete U.S. Lab outfitting for Phase 2 of ISS assembly. Flight 6A also delivers the robotic arm, which is essential to continued assembly of the ISS. The SSRMS will complete MEIT and be integrated onto the SLP in the 1st quarter of FY 2001.

- The second US flight planned for FY 2001, Flight 7A, will carry the Airlock. Once installed, the airlock will provide the station an independent EVA capability, and will bring to a close Phase 2 of ISS assembly.

- Completion of 3 of the 4 Multi-Element Integrated Test (MEIT) TC1 & 2 and begin TC3 for flight elements required for assembly flights 10A – UF3.
- Commence final integration and testing of truss segments P3/P4 and S3/S4 with their solar arrays to complete construction of the middle truss in FY 2002. The truss segments are also configured for flight in FY 2001.
- Integrated Systems Testing of Node 2 to support a 1st Qtr FY 2003 launch.
- Demonstration of station-based EVA to support up to 30 hours of EVA from the U.S. Airlock each year.
- Conduct permanent on-orbit operations, providing an estimated 8,000 hours of ISS crew support to station assembly, operations, and research.
- Complete fuel transfer systems modifications in two orbiters to provide a station reboost capability of 5-6 nautical miles per Shuttle flight.
- Launch assembly flight 8A, which will carry the S0 truss segment, SSRMS mobile transporter, and the global positioning system.
- Launch 2 Utilization Flights carrying the Microgravity Science Glovebox, refrigerator/freezer racks, the Window Observation Research Facility (WORF-1), and additional payloads for the Human Research Facility (HRF-1).
- Complete Propulsion module fabrication and assembly, and conduct qualification testing. Perform a Hot Fire test in the second quarter of FY 2001 to support a launch in the fourth quarter of FY 2002.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE STATION OPERATIONS CAPABILITY

	FY 1999	FY2000	FY 2001
		(Thousands of Dollars)	
Operations capability & construction...	83,000	49,100	22,500
Vehicle operations	258,600	454,500	432,300
Ground operations	234,700	260,000	371,700
[Construction of Facilities included]	[1,200]	[--]	[--]
Total	576,300	763,600	826,500

PROGRAM GOALS

The primary objective of the operations program is to safely and reliably deploy to orbit, assemble and operate the ISS, which requires a significant level of supporting ground operations such as crew and ground controller training and extensive planning activities. Starting years in advance of the final acceptance and launch of various ISS elements, transition of the International Space Station (ISS) vehicle program to the operations program is taking place. Sparing and logistics planning and procurements, element specific operations and anomaly preparation, and detailed integration of all capabilities and constraints of elements and ground systems are occurring across the partnership so the pieces and people operate as one system. The second major goal is to perform operations in a simplified and affordable manner. This includes NASA's overall integration of distributed operations functions to be performed by each of the international partners in support of their elements.

The first crew is to embark to ISS in FY 2000, setting in motion a progression of international crews which will allow humankind to permanently move aboard the ISS, beyond the confines of Earth. The program is preparing to furnish the crew with what is needed for them to live and productively work in the isolated and harsh environment of space for 24 hour a day, 365 days per year. This is the first time since the Skylab era in the 1970's, and the Shuttle-Mir program, that the U.S. will have an extended human presence in space. Because of its massive size and level of international participation, the ISS assembly period will span half a decade, with ISS infrastructure and logistics deployed over multiple flights from launch vehicles across the globe. Because of the program's complexity, the Space Station team has done extensive planning for operations of many different ISS vehicles on orbit. Each time an element is added to the current station, the flight characteristics and internal systems change, and the ISS stack on-orbit becomes essentially a different vehicle with different thermal constraints, drag coefficients, and other characteristics. The Space Station Program will draw on the experience derived from Skylab, the Shuttle-Mir program, and that gained from operating the Space Shuttle for nearly two decades to address the unique circumstances of building and operating an ever changing ISS vehicle.

With each successive docking of an ascent vehicle to the ISS and the transfer of its contents to the ISS, and with each increment of operations, the Program will evaluate its methods and lessons learned to develop even more efficient and effective operations.

STRATEGY FOR ACHIEVING GOALS

The Space Station operations concept emphasizes multi-center and multi-program cooperation and coordination. Operations capability development and construction provides a set of facilities, systems, and capabilities to conduct the operations of the Space Station. For the U.S. segment, the work will primarily be performed at the Kennedy Space Center (KSC) and the Johnson Space Center (JSC). KSC has developed launch site operations capabilities for conducting pre-launch and post-landing ground operations. JSC has developed space systems operation capabilities for conducting training and on-orbit operations control of the Space Station. Mission Control Center-Houston was completed for supporting the first two missions of the ISS. As ISS partners become operational, their respective ground operations functions are integrated by NASA into the unified command and control architecture, like that which has already occurred for Mission Control Center-Moscow (MCC-M) located in Kaliningrad. Beyond ISS specific operations, a consolidated approach between Space Shuttle and Space Station minimizes duplicated effort and costs for command and control, as well as training at JSC, where the initial Space Station Training Facility capability is now operational and the first crews are currently in training. Utilizing lessons learned from Shuttle-Mir, ISS crew training is knowledge and proficiency-based rather than timeline and detailed procedures based, as has been the case for the Shuttle crews.

Space Station vehicle operations provides systems engineering and integration to sustain the performance and reliability of Space Station systems, logistics support for flight hardware and launch site ground support equipment, configuration management, and any associated procurement activity. Sustaining engineering will continue to be consolidated and performed at the Johnson Space Center (JSC) to allow all flight hardware and software to be handled under a single contract. Maintenance and repair costs continue to be minimized by the application of logistics support analysis to the design, resupply/return and spares procurement processes. Flight hardware spares and repair costs will continue to be controlled by establishing a maintenance and repair capability that effectively utilizes Kennedy Space Center (KSC) and original equipment manufacturers or other certified industry repair resources.

Ground operations provides command and control, training, operations support and launch site processing. The current unified command and facility includes the Mission Control Center-Houston (MCC-H) and the Mission Control Center-Moscow (MCC-M) at Kaliningrad. As the flight elements from Europe, Japan and Canada become operational, NASA will integrate their respective ground operations functions into the unified command and control architecture. The MCC-H will be the prime site for the planning and execution of integrated system operations of the Space Station. Communication links from both Moscow and Houston will support control activities, using the Tracking and Data Relay Satellite system (TDRSS) system and Russian communication assets.

Flight controllers are being trained to operate the Space Station as a single integrated vehicle, with full systems capability in the training environment. Crewmembers are being trained in the Neutral Buoyancy Lab (NBL) and Space Station Training Facility (SSTF) on systems, operations, and other activities expected during a mission. Part-task and full hardware mockups and simulators are also being used to provide adequate training for the crew prior to flight. Integrated training, consolidation of payload and systems training facilities, the concept of proficiency-based learning and onboard training will increase the efficiency of the overall training effort.

Ground operations support provides analysis, systems definition, development, and implementation to ensure that a safe and operationally viable vehicle is delivered and can be maintained. Functions include the following: vehicle design participation and assessment, operations product development, ground facility requirements and test support, ground display and limited applications development, resource planning, crew systems and maintenance, extravehicular activity (EVA), photo/TV training, operations safety assessments, medical operations tasks, mission execution and systems performance assessment, and sustaining engineering.

Cargo integration support provides accurate, timely, and cost effective planning and layout of cargo stowage items, analytical analysis of cargo/transport systems compatibility, and physical integration of cargo items into the transport carriers and on-orbit ISS stowage systems.

Launch site processing begins prior to the arrival of the flight hardware at KSC with requirement definition and processing planning. Upon arrival at KSC, the flight hardware will undergo various processes, dependent upon the particular requirements for that processing flow. These processes may include: post delivery inspection/verification, servicing, interface testing, integrated testing, close-outs, weight and center of gravity measurement, and rack/component to carrier installation.

SCHEDULE & OUTPUTS

Space Station Training Facility (SSTF)

Primary facility for space systems operations training and procedures verification.

- SSTF Initial Ready for Training (RFT) for flight 5A (2nd Qtr FY 2000)
- SSTF Final RFT for flight 5A (3rd Qtr FY 2000)
- SSTF Initial RFT for Flight 5A.1 (2nd Qtr FY 2000)
- SSTF Final RFT for Flight 5A.1 (3rd Qtr FY 2000)
- SSTF Initial RFT for flight 6A (3rd Qtr FY 2000)
- SSTF Final RFT for flight 6A (4th Qtr FY 2000)
- SSTF Initial RFT for flight 7A (3rd Qtr FY 2000)
- SSTF Final RFT for flight 7A (1st Qtr FY 2001)
- SSTF Initial RFT for flight 7A.1 (4th Qtr FY 2000)
- SSTF Final RFT for flight 7A.1 (1st Qtr FY 2001)
- All RFT dates for flights beyond 7A.1 are template dates

Mission Control Center	Facility providing integrated command and control capabilities and support to real-time increment operations. • Mission Control Center ready to support use of ICM (2nd Qtr FY 2000) • Delivery to support flight 5A ISS Command and Control Capability (2nd Qtr FY 2000) • Complete backup control center (control center development complete) (3rd Qtr FY 2000)) • MCC Post Mariner Delivery (2nd Qtr FY 2000)
Definitize Sustaining Engineering Contract Mod Plan: March 1998 Actual: December 1998	Required to ensure prime contractor support for delivered ISS flight hardware and software is in place.
Demonstrate MCC-H to MCC-M Command Support Capability Plan: March 1998 Actual: November 1998	Development of the Mission Control Center - Houston (MCC-H) to Mission Control Center - Moscow (MCC-M) command capability. This requirement was met upon completion of end-to-end testing.
Publish MIM 98-1 Plan: April 1998 Actual: December 1998	Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through the assembly period. This update incorporates the Rev. D Modified assembly sequence.
Begin MCC-H ISS flight-following mode with flight 1A/R and 2A Plan: June 1998 Actual: November 1998	The Mission Control Center - Houston (MCC-H) is in a flight-following mode of operations until flight 5A, when NASA takes over primary real-time command and control of the ISS.
Baseline Increment Definition And Requirements Document (IDRD) for Planning Period 3 Plan: May 1999 Revised Plan: February 2000	Baselining the ISS increments in the Increment Definition and Requirements Document officially initiates increment specific Product and training Development. This typically occurs at 12 months in advance of the first increment's operations. Planning Period 3 includes increments 3-5.
Integrated Planning System Final Development Release Plan: September 1999 Actual: November 1999	The Integrated Planning System provides the planning and training analysis tools required to support long range mission and vehicle change assessments, mission design, mission and increment planning, pre-mission and contingency analysis, and direct mission support.

Conduct Increment Operations Review for Increment 1 Plan: Sept 1999 Revised Plan: February 2000	Formal program review of integrated operations planning product development
Baseline Increment Definition And Requirements Document (IDRD) for Planning Period 4 Plan: May 1999 Revised: July 2000	Baselining the ISS increments in the Increment Definition and Requirements Document officially initiates increment specific Product and training Development. This typically occurs at 12 months in advance of the first increment's operations. Planning Period 3 includes increments 6-9.
Conduct Increment Operations Review for Increment 2 Plan: Dec 1999 Revised: March 2000	Formal program review of integrated operations planning product development
Conduct Increment Operations Review for Increment 3 Plan: March 2000 Revised: July 2000	Formal program review of integrated operations planning product development
Conduct Increment Operations Review for Increment 4 Plan: November 2000 Actual:	Formal program review of integrated operations planning product development
Conduct Increment Operations Review for Increment 5 Plan: May 2001 Actual:	Formal program review of integrated operations planning product development
Crew Assigned for Increment 5 Plan: November 1999 Revised Plan: March 2000 Actual:	Official announcement of Expedition Crew for Increment

Crew Assigned for Increment 6 Plan: April 2000 Actual:	Official announcement of Expedition Crew for Increment
Publish MIM FY99 Plan: May 1999 Actual: June 1999	Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through the assembly period.
Publish MIM FY00 Plan: April 2000 Actual:	Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through the assembly period.
Publish MIM FY01 Plan: April 2001 Actual:	Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through the assembly period.

ACCOMPLISHMENTS AND PLANS

FY 1999

The first two ISS elements were successfully launched and mated during the first quarter of FY 1999. The Zarya control module, or Functional Cargo Block (FGB), was launched on November 20, 1998, by a Russian Proton Rocket from the Baikonur Cosmodrome, in Kazakstan. The FGB is an unpiloted space "tugboat" that provides early propulsion, power, and control capability and communications for the station's first months in orbit. It also provides rendezvous and docking capability to the Service Module. The FGB was built by Russia under contract to the U.S., and is owned by the U.S. The Unity connecting module (Node 1) with two Pressurized Mating Adapters (PMA1 and PMA2) were launched from the Kennedy Space Center on December 4, 1998 aboard the Space Shuttle Endeavor. This was the first of 37 planned Space Shuttle flights to assemble the station. Unity is a six-sided connector for future station components. On December 6, 1998, Endeavor's crew rendezvoused with Zarya, and, using a PMA-1, attached Unity and Zarya together. PMA-2 provides a Shuttle docking location. Eventually, Unity's six ports will provide connecting points for the Z1 truss exterior framework, the U.S. Lab, the airlock, the cupola, Node 3 and the MPLM. The crew finished connecting the two elements during three subsequent spacewalks, and also entered the interior of the fledgling ISS to install communications equipment and complete other assembly work. The two elements are operating nominally in an orbit approximately 250 miles above Earth, with some maintenance required. The Mission Control Center was ready with all the software and hardware needed to support flight 2A in the first quarter of FY 1999. Space Station Control Center (SSCC) activities included completion of the Moscow support room in preparation for the launch of the FGB in early FY 1999. Interface testing between the Mission Control Center - Houston (MCC-H) and the Mission Control Center-Moscow (MCC-M) was complete in late FY 1999. MCC-H and flight control team supported Flight 2A (December 1998) and Flight 2A.1 (May 1999). The Shuttle Discovery was launched on May 27, 1999, and performed the first docking with the International Space Station on May 29, 1999. This was a logistics flight

utilizing a Spacehab Double Cargo Module. The crew unloaded almost two tons of supplies and equipment for the station, and performed one spacewalk to install a U.S.-developed spacewalkers' crane, the base of a Russian-developed crane, and other spacewalking tools on the station's exterior for use by future assembly crews. Discovery fired its thrusters to reboost the station's orbit and then undocked on June 3, 1999. The Space Station Training Facility was ready for Expedition 1 training in September 1999. Other major accomplishments in the SSTF include the delivery of training software for flights 2A.1, 2A.2, 3A, 4A. Assembly critical spares for flights through 12A.1 have been defined and are being manifested on appropriate shuttle flights. A new Logistics and Maintenance post production support contract was negotiated with Boeing. Station Program Implementation Plan (SPIP) documentation has been baselined, with international partner agreements. A new assembly sequence (Rev. E) was baselined in June 1999.

Launch site processing work supported launch site testing and launch of ISS flights 2A and 2A.1. Space Station operations at KSC supported the first four test configurations of MEIT. Planning and processing support for ISS 7A through UF-1 was provided and launch site ground support equipment in support of resupply/return flight processing will be delivered. For operations planning and cargo integration, MPLM (flight 5A.1) and airlock (flight 7A) stowage accommodations have been processed and on-orbit stowage planning for flights 2A through 5A have been worked. Nine Zero-G stowage racks were procured and installed into the Lab (flight 5A).

The Super Guppy aircraft transported the US Lab, S0 structural test article and flight element, airlock, and US Lab structural test article elements to various locations.

Sustaining engineering for FY1999 included providing engineering and technical support required to maintain the hardware post-DD250 for flights 2A - 7A. Real-time engineering support was provided to the following missions/stages and supported Progress launches: 1A/R, 2A, 1R and 2A.1. A remote real-time data access capability for in-home and office use was implemented. Sustaining engineering products for flights 2A -10A were produced. Agreements with MSFC, JSC and GRC on sustaining engineering support and required products and schedule as well as the basic sustaining engineering schedule and baseline schedules for flights 3A - UF-3 were refined. Bilateral agreements on sustaining engineering were baselined with Agenzia Spatiale Italiano (ASI), Rosaviakosmos, and CSA.

FY 2000

FY 2000 will see the initial operation of ISS with three person permanent crew. Space Station Operations will support U.S. missions 2A.2, 3A, 4A and 5A. It will also support Russian missions delivering the Service Module and sending the first crew to ISS, as well as 5 other Soyuz/Progress flights.

The Zvezda Service Module (SM) is now targeted for launch aboard a Russian Proton rocket from the Baikonur Cosmodrome in Kazakstan. The SM will be launched without a crew aboard and will dock with the orbiting ISS by remote control. In addition to early station living quarters, the SM will also provide life support, navigation, communications, guidance and propulsion to the new station. Flight 2A.2 is a logistics flight scheduled to be launched aboard the Shuttle Atlantis. Logistics and supplies will be transferred to the new space station, and astronauts will begin orbital checkout and setup of the new living quarters. In addition, a

spacewalk will be performed to install the Russian Strela crane telescoping boom. The station will remain unpiloted after Atlantis undocks. Flight 3A will be launched aboard the Space Shuttle Discovery, and will include the Integrated Truss Structure Z1, PMA-3, the KU-band communications system, and Control Moment Gyros (CMG's). The first ISS crew, designated Expedition 1, will be launched aboard a Russian Soyuz spacecraft. This begins the permanent human presence in space aboard the ISS. This crew will remain aboard the ISS for 4 months before departing. The Soyuz will remain attached to the ISS to provide assured crew return capability without the Shuttle present. Flight 4A, launched aboard the Space Shuttle Endeavor, will deliver the Integrated Truss Structure element P6, a photovoltaic module and two radiators, thereby providing U.S. power and cooling. The S-band communications system will be activated for voice and telemetry. Flight 5A, launched aboard the Atlantis, carries Destiny, the U.S. Laboratory Module. Destiny will be launched with 5 system racks already installed. With the delivery of the electronics in the lab, the CMG's will be activated, providing electrically powered attitude control.

Space Station Training Facility will support crew and flight controller training for Flights 2A.2 through 8A. MCC-H will support flights 2A.2 through 5A. Primary real-time ISS vehicle control responsibility will be transferred from MCC-M to MCC-H on Flight 5A. MCC-H software loads will be delivered for 4A- UF-2. Standalone Payload Training Capability (PTC) will be ready for flight 5A.1 & the integrated PTC will be ready for flight UF-3.

Training for Expedition 1 and 2 will be completed in FY 2000. Expedition 1 will launch and be returned to earth with the launch of Expedition 2, which is scheduled for the 1st quarter of FY 2001. Training for Expeditions 3 and 4 will continue throughout FY 2000. Training for Expeditions 5, 6 and 7 will begin in FY 2000.

Launch site processing activities continue in support of launch site testing and launch of ISS flights 3A through 7A.1. Station operations will support regression testing for MEIT 1 (2A, 3A, 4A, 5A and 6A) and MEIT 2 (integrated truss elements) both conducted in FY 2000. Planning and processing support will be provided for ISS flights 9A.1 through 13A, and launch site ground support equipment will be delivered in support of re-supply/return flight processing. Operations planning and cargo integration work will include the processing of stowage accommodations and on-orbit stowage. In FY 2000, the program will continue to identify and issue additional Provisional Item Orders (PIOs) for spares hardware and repair parts. Transportation activities will continue utilizing the Super Guppy for oversize element transportation, and the project will continue to manifest assembly critical spares.

Sustaining engineering activities for FY 2000 includes providing additional engineering and technical support required to maintain the hardware post-DD250 for flights 8A - 11A. Real-time engineering support will be provided to the following missions/stages and supporting Progress launches: flights 3A, 4A, and 5A. Sustaining engineering products for flights 6A through UF5 will be produced. Agreements with MSFC, JSC and GRC on required products and schedule, as well as baseline schedules for flights UF4 through 16A, will continue to be defined. Bilateral agreements on sustaining engineering with ESA and NASDA will be developed.

FY 2001

In FY 2001 the ISS program will conduct the first full year of permanently crewed on-orbit operations. It will also be the first full year of U.S. leadership of the primary real time ISS vehicle control function. ISS will begin operations with contributions from

additional international partners. The Canadian Space Station Remote Manipulator System (SSRMS) will be installed on the ISS, and the program will use the MPLM from Italy for the first time.

Early in the fiscal year, a Russian Soyuz rocket will launch the Docking Compartment (DC-1). This will provide additional egress, an ingress location for Russian-based spacewalks, and a Soyuz docking port. Flight 5A.1, launched aboard the Discovery, will ferry the Expedition 2 crew to the station and return the first crew to earth. It will carry Leonardo, the first Multi-Purpose Logistics Module (MPLM), with equipment racks to outfit the lab module. It will also deliver the first research rack, HRF #1. Flight 6A, launched aboard the Shuttle Endeavor, will carry Raffaello, the first Italian-built Multi-Purpose Logistics Module (MPLM), including six systems and two storage racks for the U.S. Lab. Also aboard are a UHF antenna to provide space-to-space communications capability for U.S.-based spacewalks, and the Canadian SSRMS (station mechanical arm) required to perform assembly operations on later flights. Flight 7A, launched aboard the Atlantis, will deliver the Joint Airlock and the High Pressure Gas Assembly. The former will provide station-based extravehicular capability for both U.S. and Russian spacesuits, while the latter will support spacewalk operations and augment the Zvezda Service Module gas resupply system. The addition of this hardware completes Phase II of the ISS, indicating that it has achieved a certain degree of self-sufficiency and capability without the presence of an orbiter. Four more flights will occur in FY 2001. Flight 7A.1 would use the Shuttle Endeavor to ferry the 3rd resident crew to the station. It would also carry an Italian-built MPLM module containing U.S. stowage racks and International Standard Payload Racks (ISPR's). The second U.S. built spacewalkers' crane will be attached to the exterior of the station. UF-1, the first utilization flight, will utilize Atlantis, and will include an MPLM and PV Module Batteries. The MPLM will contain experiment racks for the U.S. Lab and two storage racks. Flight 8A, planned to be launched aboard the Endeavor during the early summer, carries the fourth resident crew and returns the second to earth. The center segment of the station truss, ITS S0, and the Canadian Mobile Transporter are also aboard. UF-2, a second utilization flight, is the last flight being planned for FY 2001. It will be launched aboard the Atlantis, and will carry an MPLM containing experiment racks and three stowage and resupply racks to the station. Also aboard will be the Mobile Base System, to be attached to the Mobile Transporter, thus completing the Canadian Mobile Servicing System (MSS).

Training for Expedition crews 3 and 4 will be completed. Expedition crews 2,3, and 4 will be launched to ISS and 1,2,and 3 will be returned. Training for Expedition crews 5, 6 and 7 will continue in FY 2001; they are scheduled to be completed in FY 2002. The training template suggests that Training for Expeditions 8-11 will begin in FY 2001. Space Station Operations will provide real time support to flights 5A.1, 6A, 7A7A.1, UF-1, 8A , UF-2, 9A and 11A. The program will also support 6-7 planned Progress flights and two Soyuz flights. IDRDs for planning periods in 2002 and 2003 will be baselined.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE STATION RESEARCH

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Research Projects	191,200	246,200	337,100
Utilization Support	143,300	148,200	118,300
Mir Support (including Mir Research)	2,000	--	--
Total	336,500	394,400	455,400

PROGRAM GOALS

NASA will utilize the ISS as an interactive laboratory in space to advance scientific, exploration, engineering and commercial activities. As a microgravity laboratory, the ISS will be used to advance fundamental scientific knowledge, foster new scientific discoveries for the benefit of the U. S., and accelerate the rate at which it develops beneficial applications derived from long-term, space-based research. The ISS will be the world's premier facility for studying the role of gravity on biological, physical and chemical systems. The program will deliver the capability to perform unique, long-duration, space-based research in cell and developmental biology, plant biology, human physiology, biotechnology, fluid physics, combustion science, materials science and fundamental physics. The experience and knowledge gained from long-duration human presence on the ISS will help us learn how to more safely and effectively live and work in space. ISS will also provide a unique platform for making observations of the Earth's surface and atmosphere, the sun, and other astronomical objects, as well as the space environment and its effects on new spacecraft technologies.

As NASA moves into the ISS era, there will be a major transition from the current short-term on-orbit experimentation program to the long-term research efforts made possible by the capabilities of the ISS. The core of the ISS research program will be eight major research facilities: the Gravitational Biology Facility, the Centrifuge Facility, the Human Research Facility, the Materials Science Research Facility (formerly known as the Space Station Furnace Facility), the Biotechnology Facility (which includes Protein Crystal Growth activities), the Fluids and Combustion Facility, the Window Observational Research Facility, and the Low Temperature Microgravity Physics Facility. In addition to the eight major facilities, NASA will develop common-use Laboratory Support Equipment and the Expedite the Processing of Experiments to Space Station (EXPRESS) racks and pallets for the Station.

STRATEGY FOR ACHIEVING GOALS

In 1996, NASA consolidated management of the ISS research and technology, science utilization, and payload development with the ISS development and operations program to enhance the integrated management of the total content of the ISS budget. The Space Station Program Manager is responsible for the cost, schedule and technical performance of the total program. The Office of Life and Microgravity Sciences and Applications (OLMSA), Office of Earth Science, and Office of Space Science remain responsible for establishing the research requirements consistent with the overall ISS objectives, and funding the principle investigators. The budget reflects this consolidation by funding research capability development and Station-related Space Product Development activities within the ISS account. There is close coordination among the NASA science offices and the ISS program to ensure that the research capabilities provided by the ISS are tightly coupled to the needs of the various research communities it will serve.

In response to House Report 105-610, accompanying H.R. 4194, NASA submitted a report to Congress on September 17, 1999 outlining a plan for transitioning administrative authority for the ISS Research Program to OLMSA. The new Space Utilization and Product Development Division within OLMSA was designated to assume administrative authority over the research program for the HEDS Enterprise. It will be the principal interface with the Payloads Office located at the Space Station Program Office, Johnson Space Center. The transition will occur during FY 2000. No restructuring of the budget is envisioned.

NASA is currently evaluating options for a potential new facility at the Kennedy Space Center. Under one option, the Space Experiment Research and Processing Laboratory (SERPL) would be constructed in partnership with the State of Florida and would provide a world-class laboratory facility with the capability to host ISS experiment processing and biological and life sciences research. The State of Florida would provide the bulk of the funding required for such a facility, but NASA would also be responsible for a small portion of the initial design and facility construction costs. Any NASA facility funding requirements would be within existing and planned budgets of the Human Exploration and Development of Space (HEDS) Enterprise, and incurred in the FY 2000-FY 2002 timeframe.

NASA also delivered to Congress the Commercial Development Plan for the ISS during the first Quarter of FY 1999. Several independent marketing and management studies are currently underway. NASA is discussing several commercial opportunities with U.S. industry. Recently, the White House and Congress approved the "International Space Station Commercial Demonstration Program" initiative to establish a pricing policy for commercial use of ISS facilities in support of the commercial development of space.

The Revision E Assembly Sequence and research budget rephasing for FY 2000 – FY 2003 have impacted the planned research program. While still emphasizing early research capabilities, major payload facilities have been delayed on average about three to four months. The delivery schedule for research facilities continues to closely track the buildup of ISS accommodations to ensure the research programs ramp up as soon as capability becomes available. The research program will continue to be aligned with the availability of on-orbit resources, including crew time, power and upmass capabilities.

The STS-95 research mission was conducted during October 1999, and an additional research transition (STS-107) mission was added to the Shuttle manifest in early 2001 to mitigate research opportunity gaps resulting from the delays in the ISS assembly and

utilization schedules. For the FY 2001 mission, the ISS research program will fund payload engineering and integration activities, some experiment unique hardware, and a portion of the carrier cost requirement. The remaining carrier costs and grants and contract costs for the principle investigators will be funded by OLMSA.

During the early assembly period, the EXPRESS rack program will continue to provide valuable flight opportunities for middeck locker scale experimentation and product development in the areas of biotechnology, biomedical sciences, fluid dynamics and combustion research. Despite delays to the utilization flight plan, NASA effectively doubled U.S. research crew time and stowage through our crewtime negotiations with Russia. The new crew time-stowage balance will position the U.S. for greater experiment productivity from the beginning of the research program. As a direct result, the research program will be significantly enriched because it will allow a greater number of experiments to proceed for longer periods and at increased frequency, thus obtaining many more processed samples and empirical data. Additionally, the ISS program will take advantage of the new logistics flights capabilities of the rephased assembly sequence and will maintain early outfitting by adding the Human Research Facility and two EXPRESS Racks on assembly flights 5A.1 and 6A.

Significant progress continues to be made in the establishment of international participation in the provision of U.S. research facilities. The Centrifuge, Centrifuge Accommodation Module, and Life Sciences Glovebox development continue under the Implementing Agreement with the National Space Development Agency of Japan (NASDA) as partial offset for the Shuttle launch of the JEM. The cryogenic freezer racks and the Minus-Eighty Degree Laboratory Freezer (MELFI) and the microgravity science glovebox for ISS will be provided by the European Space Agency (ESA) under a March 1997 Memorandum of Understanding. The Brazilian Space Agency (AEB), as a participant in the NASA program, will provide the Technology Experiment Facility, Window Observational Research Facility Block 2, and the EXPRESS Pallet, under an Implementing Arrangement between the U.S. and Brazilian governments.

The Research program is aligned in the following components: Research Projects (including Biomedical Research and Countermeasures, Gravitational Biology and Ecology, Microgravity Research, Space Products Development, Earth Observation Systems, and Engineering Technology) and Utilization Support.

Research Projects

Biomedical research facilities and activities include the Human Research Facility (HRF), the Crew Health Care Subsystem (CHeCS) and the associated payload development. The HRF provides an on-orbit laboratory that will enable life science researchers to study and evaluate the physiological, behavioral, and chemical changes in human beings induced by space flight. Research performed with the HRF will provide data relevant to long adaptation to the space flight environment. Many capabilities developed for the HRF have Earth-based application. HRF hardware will enable the standardized, systematic collection of data from the Space Station's crewmembers, which the medical and research community will require in order to assure crew health. Once verified on-orbit, the HRF will also be used to conduct basic and applied human research and technology experiments.

In addition to the biomedical research that will be conducted using the HRF, NASA's biomedical activities aboard the ISS will include the suite of hardware necessary to protect crew health. CHeCS will support medical care requirements for the ISS crew following

deployment of the U.S. Laboratory module. CHeCS hardware will provide inflight capabilities for ambulatory and emergency medical care. It will support monitoring of medically necessary environmental parameters, along with capabilities for counteracting the adverse physiological effects of long-duration space flight. Hardware commonality between CHeCS and the HRF is being evaluated, with the synergy between the two programs resulting in maximum research efficiency and cost savings.

The Gravitational Biology and Ecology facilities and activities including the Gravitational Biology Facility (GBF), the Centrifuge Facility, and associated payload development activities, comprise a complete on-orbit laboratory for biological research. The GBF will design, develop, and conduct the on-orbit verification of ISS research equipment to support the growth and development of a variety of biological specimens, including animal and plant cells and tissues, embryos, fresh and salt water aquatic organisms, insects, higher plants, and rodents. The GBF will support specimen sampling and storage as well as limited analysis activities. The GBF modular design will accommodate the incremental development of experiment capabilities in a manner consistent with evolving ground and flight science needs of the research community.

The Centrifuge Facility includes two habitat holding systems, a centrifuge rotor, life sciences glovebox, and two service system racks. Under the NASA-NASDA Agreement in Principle, NASDA will provide the centrifuge rotor, life sciences glovebox and the Centrifuge Accommodation Module.

Microgravity Research activities include development of the Fluids and Combustion Facility, Material Science Research Facility, Biotechnology Facility, Low-Temperature Microgravity Physics Facility, and payload development.

The Fluids and Combustion Facility (FCF) supports research on interfacial phenomena, colloidal systems, multiphase flow and heat transfer, solid-fluid interface dynamics, and condensed matter physics, and definition of the mechanisms involved in various combustion processes in the absence of strong buoyant flows. The FCF is a three-rack payload. The Fluids Integration Rack is designed to accommodate several multi-purpose experiment modules that are individually configured with facility-provided and experiment-specific hardware to support each fluids experiment. The Combustion Module houses combustion chamber that is equipped with ports to allow an array of modular diagnostic systems to view the experiment. The facility core rack will provide common support systems for both the combustion and the fluid payload racks; however, the combustion and fluid racks are being designed to operate as standalone hardware during the Station assembly period with more constrained capability.

The Space Station Materials Science Research Facility (MSRF) will be used to study underlying principles necessary to predict the relationships of synthesis and processing of materials to their resulting structures and properties. Cooperative efforts are underway with the international science community that will assist in the development of some discipline-specific furnace modules for use by the U.S. science community, thus leveraging the hardware development investments undertaken by NASA.

The Biotechnology Facility (BTF) supports research in the areas of protein crystal growth and cell tissue cultures, which include studies on the maintenance, and response of mammalian tissue cultures in a microgravity environment. The facility will provide a support structure as well as integration capabilities for individual biotechnology experiment modules. Its modular design will provide the flexibility to accommodate a wide range of experiments in cell culturing and protein crystallization. The facility will

accommodate changes in experimental modules and analytical equipment in response to changes in science priorities or technological advances. The BTF will support a large group of academic, industrial and government scientists.

The objective of the Low Temperature Microgravity Physics Facility (LTMPF) is to investigate the fundamental behavior of condensed matter without the complications introduced by gravity. Primary LTMPF research will study the universal properties of matter at phase transitions and the dynamics of quantum fluids. The LTMPF will be a remotely operated payload package attached to the Japanese Exposed Facility of the Station and is expected to improve measurements by a factor of 100 over similar terrestrial tests. This attached payload facility will support two independent research instruments simultaneously (at a temperature between 0 and 4 degrees Kelvin) and provide 6 to 8 months of microgravity operation between reservicing and hardware changeout.

NASA's commercial research programs for ISS will take advantage of the new opportunities for space flight operations provided by the ISS, and a distinctly new operating environment. Among other activities, the commercial research programs for the ISS will concentrate on commercial protein crystal growth and plant growth research. The commercial protein crystal growth activities for ISS are underway at the Center for Macromolecular Crystallography, and plant growth research at the Wisconsin Center for Space Automation and Robotics, the Center for Bioserve Space Technologies, and their industrial affiliates.

The Stratospheric Gas and Aerosol Experiment (SAGE III) will measure chemical properties of the Earth's atmosphere between troposphere and the mesosphere. A key aspect of this research will investigate effects of aerosols on ozone depletion in the atmosphere. SAGE III is a payload attached to the outside of the Station and will be mounted on an ESA-provided precision-pointing platform.

The Window Observational Research Facility (WORF) will be located in the U.S. Laboratory Module at the zenith- (Earth) pointing window location. The WORF, which includes a high-quality window and a special rack structure to support optical equipment attachment, will provide a crew workstation for research-quality Earth observations of rare and transitory surface and atmospheric phenomena. The first version, the Block 1 WORF, is being developed as a research testbed for early utilization during the ISS assembly sequence. A more mature Block 2 version will be provided by the Brazilian Space Agency as a subsequent upgrade.

The primary objective of Advanced Human Support Technology (AHST) is the definition, development and testing of advanced technology hardware and processes in support of humans-in-space engineering and life support, and extra-vehicular activity. Specific areas of potential research which have been identified include closed loop life support systems (CO_2 reduction and O_2 generation), biological water recovery, advanced telemetric biosensors, and wearable computers. In order to take advantage of related activities and expertise, the AHST projects have been merged with Engineering Research Technology.

The Engineering Research Technology (ERT) program will maximize the use of the ISS as a unique on-orbit laboratory, thereby fostering the partnerships with other U.S. Government, industrial and academic communities. The ERT program will identify and define innovative technology concepts, develop these concepts into flight experiments, and perform the necessary laboratory-scale investigations on-board the ISS to validate the physical characteristics advanced by these concepts. The program promotes the fast track implementation of these experiments. At the same time, the ERT program will obtain proposals for the facilities, which can provide the necessary support for one or more experiments to operate without duplication of functions.

The AHST program activities merged into ERT will identify, develop, and perform flight demonstration, testing, and validation of selected advanced technologies consistent with Space and Life Sciences and the NASA Strategic Plan. These flight experiments will demonstrate miniaturization, low power consumption, high reliability, ease of use, and cost effectiveness for technologies which play a role in life support, environmental monitoring and control, biomedical research and countermeasures, crew health care, and extravehicular activities. This will provide a means for taking advanced technologies, which may originate within or outside NASA, to levels of maturity beyond what could be accomplished through ground testing alone. This effort will enable rapid accommodation of advanced technologies into operational systems on the ISS. The initial facility payload on the Station is planned as a single modified EXPRESS rack, which will support rotation of subrack payload investigations with a typical duration of 90-180 days.

Utilization Support

Utilization Support provides the necessary capabilities to integrate and operate payloads of commercial, academic and government researchers on the ISS. These capabilities provide the facilities, systems and personnel to support the ISS user community in efficient and responsive user/payload operations. Support is provided for flight and ground capabilities to ensure efficient and complete end-to-end payload operations. Telescience operations are supported to maintain the highest flexibility for both the user community and NASA at the lowest cost. NASA and International Partner payload operations are integrated to ensure compatible use of ISS resources and to resolve payload requirement conflicts.

Utilization Support provides pre-flight payload engineering integration, verification and checkout support, payload operations integration, payload training, mission planning, real-time operations support, data processing and distribution and launch site support. Services begin with initial definition of the payload for flight and continue throughout onboard ISS operation and return of experiment's data and equipment to the user. Services include documentation of interfaces and verification requirements, training of ground and flight teams, and development and execution of mission plans to meet the needs of the user community. Mission execution activities have been streamlined to allow greater payload operational flexibility.

On the ground, the Payload Operations Integration Center (POIC)/United States Operations Center (USOC), Payload Data Services System (PDSS), and the Payload Planning System (PPS) provide the user community with the tools and resources to access ISS flight payload services and conduct operations from their home laboratories. For those users who do not have access to command and telemetry processing capability at their home location, the USOC provides accommodations for them to conduct their ground-based operations support. Development cost of these systems has been reduced by utilizing a generic architecture, which supports multiple programs including Space Shuttle and the Chandra X-Ray Observatory (CXO, formerly known as AXAF).

Utilization Support assists payload developers through the provision of payload checkout and verification tools needed for development and verification of their payloads. Among the systems provided are the Payload Rack Checkout Unit (PRCU) and the Suitcase Test Environment for Payloads (STEP). A Payload Data Library (PDL) will provide a single electronic interface for payload developers to provide the requirements and data necessary for the ISS to integrate and operate their experiments.

NASA's Utilization Support also provides the necessary integration across all International Partner payload planning and operations to ensure efficient, compatible use of ISS payload resources.

In addition to the major facility-class payloads, NASA plans to fly smaller, less complex payloads on the ISS which will typically have more focused research objectives and shorter development time cycles and will be easily adapted to a variety of users. An EXPRESS Rack concept was adopted to drastically shorten user pre-flight payload preparation activities. The EXPRESS rack will enable a simple, streamlined analytical and physical integration process for small payloads by providing standard hardware and software interfaces. The project flight and ground systems were successfully demonstrated on a precursor flight of an EXPRESS rack in FY 1997 on the MSL-1 Spacelab mission. The EXPRESS pallet project provides small attached payloads with a similar streamlined process and hardware and software interfaces. The Brazilian Space Agency is responsible for developing the EXPRESS pallets for NASA.

Laboratory Support Equipment (LSE) is under development for the ISS to support Life and Microgravity Sciences and other experiments. This equipment includes a digital thermometer, video camera, passive dosimeter, specimen labeling tools, microscopes, small mass measurement device, pH meter, and an incubator. A cryogenic transport freezer and low-temperature onboard freezers are also being developed to support ISS research activities.

SCHEDULE & OUTPUTS

Research Projects

Centrifuge & Life Sciences Glovebox CDR Plan: Rotor 3rd Qtr FY 2001 LSG 4th Qtr FY 2000 Actual:	The Life Sciences Glovebox PDR was completed during late 1999. The Centrifuge Rotor PDR is scheduled for early 2000.
Fluids Combustion System PDR Plan: 4th Qtr FY 2000 Actual:	The FCF program was restructured and a Hardware Concept Review was conducted in FY 1998. A PDR is planned for FY 2000. The third rack of the FCF has been deferred until 2005.
Materials Science Research Facility Rack 1 CDR Plan: 4th Qtr FY 2000 Actual:	The SSFF project was renamed the MSRF, restructured and re-baselined in FY 1998. A PDR was completed during 1999. The CDR for the first rack will be held in late 2000.
CHeCS Complete manufacture and assembly of qualification hardware Plan: 3rd Qtr FY 1997	CHeCS provides crew health care system hardware included in the health maintenance system, and the countermeasure system required to ensure crew health and safety. While the CHeCS rack is not qualified at a system level, the date listed represents the qualification of the last item

Actual: 2nd Qtr FY 1999	integrated into the rack.
Human Research Facility Rack 1 CDR Plan: 1st Qtr FY 1999 Actual: 1st Qtr FY 1999	HRF Rack 1 subrack integration is complete. On-dock delivery to KSC is planned for early 2000 to support launch on 5A.1.
Gravitational Biology Facility Rack 1 Fab/Assy/Test Plan: 4th Qtr FY 2000 Actual:	The GBF Habitat Holding Rack 1 will begin Fabrication/Assembly/Testing during late 2000.
Biotechnology Facility PDR Plan: 3rd Qtr FY 2000 Revised 3rd Qtr FY 2001	The BTF has been deferred until 2005.
Materials Science Research Facility Rack 2 CDR Plan: 4th Qtr FY 2000 Revised: 1st Qtr FY 2003	The 2nd and 3rd racks of the MSRF have been deferred until 2005.
Low Temperature Microgravity Physics Facility PDR Plan: 2nd Qtr FY 2000 Actual:	The LMTPF completed a Conceptual Design Review during early 1999. A PDR is planned for mid 2000.
Human Research Facility Rack 2 CDR Plan: 2nd Qtr FY 2000 Actual:	The HRF Rack 2 will complete a CDR and begin Fabrication/Testing during FY 2000.
Utilization Support	
EXPRESS Racks 1 & 2 Final Testing and Reviews Plan: 2nd Qtr FY2000 Actual:	Structural buildup, final documentation, safety reviews and testing are in work. Subrack integration and final testing for the first 2 racks will be completed in early 2000. The first two EXPRESS Racks will be on-dock at KSC during mid 2000.
Complete POIC/USOC and facilities outfitting	Payload Operations Integration Center (POIC) and U.S. Operations Center (USOC) at MSFC will complete initial outfitting during early 2000.

Plan: 1st Qtr FY 2000
Actual:

EXPRESS Pallet PDR
Plan: 4th Qtr FY 1999
Actual:

Brazil is building the EXPRESS Pallets. The PDR has been delayed due to funding problems with the Brazilian Government.

Complete PP2 Baseline IDRD
Plan: 1st Qtr FY 1998
Actual: 1st Qtr 1998

The Interface Definition and Requirements Document (IDRD) describes the on-orbit resources (volume, power, data, etc.) allocated to all payloads. The IDRD for Planning Period 2 was baselined in November 1998.

WORF Block 1 CDR
Plan: 2nd Qtr 2000
Actual:

The Window Observational Research Facility (WORF) completed a Systems Requirement Review and Preliminary Requirements Review during 1999. A CDR is planned for early 2000.

Payload Crew Training
Plan: 1st Qtr FY1999
Actual: 1st Qtr FY 1999

Payload Crew training began during early 1999.

PDSS Initial Operations Capability
Plan: 2nd Qtr FY 1999
Actual: 2nd Qtr FY1999

The capability to process Ku-band (payload) and S-band (core systems) telemetry data for the 5A.1 and subsequent missions was developed.

Communications Link Activation
Plan: 2nd Qtr FY 2000
Actual:

The initial communication link activation from the Huntsville Operations Support Center (HOSC) to the Space Station Control Center (SSCC) to support payload training and operations occurred during the 3rd Quarter of FY1999. Full communication link activation is scheduled for mid 2000.

PPS Build 2
Plan: 1st Qtr FY2000
Actual:

The Payload Planning System (PPS) capabilities required to support Cadre-Payload Developer Training was completed during mid 1999. Build 2 is planned for early 2000.

ACCOMPLISHMENTS AND PLANS

Research Projects - FY 1999

Development of ISS facility-class payloads made significant progress during FY 1999. Three of five research racks were delivered in preparation for launch on 5A.1, 6A and 7A.1. The payload planning process was simplified to reduce documentation and risk. The

development integration template was revised to reduce product delivery milestones and shorten integration timeframes. Detailed payload manifests were approved for 2000 and 2001.

Rack 1 of the Human Research Facility (HRF) completed a CDR during early in FY1999. Rack 1 subrack integration has been completed and the HRF is in final verification testing. The HRF and subrack level experiments will be delivered on-dock to KSC during early 2000 in preparation for flight on 5A.1. Rack 2 of the HRF has been accelerated to fly on 12A.1. Flight units of the following hardware were delivered: ultrasound, GASMAP, computer workstation. The HRF Flight Prototype Rack was included in the MEIT at KSC in mid-FY 1999. The test verified the ISS interfaces (electrical, thermal, communications, data, etc.), ISS payload test tools, and HRF integration tools.

The Microgravity Science Glovebox completed a CDR during in early FY1999 and continues in Fabrication/Assembly/Testing in preparation for launch on UF-1. The Microgravity Science Glovebox Ground Unit was delivered to MSFC in late FY1999. The Minus Eighty-Degree Laboratory Freezer completed a CDR and initiated Fabrication/Assembly/Testing in preparation for launch on UF-1.

The Fluids and Combustion Facility (FCF) Combustion Integrated Rack completed a PDR and a Phase 1 Safety Review. The FCF Fluids Integration Rack continued in the design phase. The 3rd rack of the FCF was deferred until 2005

The Microgravity Science Research Facility (MSRF) Experiment Carrier completed a PDR. The MSRF Racks 2 and 3 were deferred until 2005. The Biotechnology Facility was also deferred until 2005.

The Life Sciences Glovebox completed a PDR and a KC-135 mock-up test to evaluate glovebox operations. The Centrifuge Rotor PDR was rescheduled for 2000. The Gravitational Biology Facility (GBF) continued build-up of the qualification hardware. The GBF Habitat Holding Rack 1 and Cell Culture Units continued in detailed design. The GBF Biomass Production System and Avian Development Facility continued in Assembly/Testing in preparation for launch on UF-1 and UF-2.

The Low Temperature Microgravity Physics Facility completed a Conceptual Design Review. The Stratospheric Gas and Aerosol Experiment (SAGE III) completed an instrument CDR and continued in Assembly/Testing. The Hexapod pointer system completed a PDR. In addition, flight instruments assembly and subsystem testing were initiated during FY 1999. As part of the ESA Early Utilization Agreement, ESA will provide a hexapod pointing platform for SAGE III, which will provide the 1-degree of pointing accuracy, required by the payload.

The Engineering Research Technology program completed a PDR for the Optical Communications Demonstration (OCD) project. The Attitude Control and Energy Stowage Experiment (ACESE) project was restructured and renamed the Flywheel Energy Storage System (FESS) and continued in Assembly/Testing.

Research Projects - FY 2000

During FY 2000, NASDA will complete the Life Science Glovebox CDR and initiate Fabrication/Assembly/Testing. The Centrifuge Rotor Facility will complete a PDR and continue detailed design. The GBF Habitat Holding Rack 1 will initiate

Fabrication/Assembly/Testing. The GBF Cell Culture Unit will conduct a CDR, the Advanced Animal Habitat a PDR, and the Plant Research Unit a PRR. The GBF Biomass Production System and Avian Development Facility will continue Assembly/Testing in preparation for launch on UF-1 and UF-2.

The HRF Rack 1 will be delivered on-dock to KSC in preparation for launch on 5A.1. The HRF Flight Prototype Rack will be included in the MEIT End-to-End Test in early 2000. This test will include full end to end flow of commands and telemetry to HRF in the U.S. Lab from the Telescience Center. The HRF Rack 2 will complete a CDR and initiate Fabrication/Assembly/Testing.

The Microgravity Sciences Glovebox and Minus Eighty-Degree Laboratory Freezer (MELFI) will continue in Fabrication/Assembly/Testing in preparation for launch on UF-1.

The FCF project activities planned for FY 2000 include a Fluids Integration Rack CDR and Phase 1 Safety Review. The Combustion Integrated Rack will complete a CDR, Phase 2 Safety Review and continue manufacturing/assembly.

The MSRF Rack 1 will complete a PDR, CDR and initiate Fabrication/Assembly/Testing. The MSRF Experiment Carrier and Inserts will complete CDRs. The Biotechnology Facility will conduct a Requirements Design Review. EXPRESS Rack level biotechnology and fluid physics payloads will be launched on 6A and 7A.1.

The Low Temperature Microgravity Physics Facility will complete a PDR, CDR and initiate Fabrication/Assembly/Testing in preparation for launch on UF3. The SAGE III and Hexapod units will conduct CDRs and continue Fabrication/Assembly/Testing.

The Engineering Research Technology Program will conduct a CDR and initiate Fabrication/Assembly/Testing for the OCD project. FESS will complete a PDR and continue in Assembly/Testing. PDR reviews will be conducted for the Flexible Control Structures; Photovoltaic Engineering Testbed and the Micron Accuracy Deployment Experiments. The Advanced Human Support Technology (AHST) facility will conduct a Requirements Design Review.

Research Projects - FY 2001

During FY 2001, the research program will maximize early research opportunities on the HRF Rack 1, Express Racks, Microgravity Sciences Glovebox and the Window Observational Research Facility. The program will also continue development activities on the remaining facility-class payloads.

The HRF Rack 2 will complete Assembly/Testing and be delivered on-dock to KSC in preparation for launch on 12.1.

The Life Sciences Glovebox will continue Fabrication/Assembly/Testing. The Centrifuge Rotor and GBF Advanced Animal Habitat will complete CDRs and initiate Fabrication/Assembly/Testing. The GBF Cell Culture Unit will continue in Assembly/Testing. The GBF Biomass Production System and Avian Development Facility will continue Assembly/Testing and be delivered to KSC in preparation for launch on UF-1. The GBF Habitat Holding Rack 1 will initiate Fabrication/Assembly/Testing.

The Microgravity Sciences Glovebox and Minus Eighty-Degree Laboratory Freezer (MELFI) will complete integration testing and KSC processing in preparation for launch on UF-1.

The FCF project and Fluids Integration Rack will complete CDRs. The Combustion Integration Rack will continue Fabrication/Assembly/Testing.

The MSRF Rack 1 will continue Fabrication/Assembly/Testing. The MSRF Experiment Carrier will initiate Fabrication/Assembly/Testing. The ISS Biotechnology Facility will complete a PDR. EXPRESS Rack level biotechnology and fluid physics payloads will continue operations in the EXPRESS Racks on the ISS.

The Low Temperature Microgravity Physics Facility will continue Fabrication/Assembly/Testing. The SAGE III and Hexapod units will continue Fabrication/Assembly/Testing.

The Engineering Research Technology Program will continue Fabrication/Assembly and Testing for the FESS and OCD projects; and conduct CDR reviews for the Photovoltaic Engineering Testbed and the Micron Accuracy Deployment Experiments. The Advanced Human Support Technology (AHST) facility will conduct a PDR.

Utilization Support - FY 1999

During FY 1999, preparations continued to ensure capabilities readiness to support on-orbit payload operations. Payload Crew Training was initiated for Expedition 2 Crew to support Increment 2 and 3 payloads on the HRF and EXPRESS Racks. A Payload Readiness Review was completed for flights 5A.1, 6A and 7A.1.

The Huntsville Operations Support Center (HOSC) and POIC were declared operationally ready to support 5A.1 and 6A payload operations. POIC internal simulations were conducted to support early payload operations. Many of the flight products were completed and integrated with the systems operations products. The first payload crew began training for the missions and the integrated engineering and operational assessments were performed for the payload complements. Development continued on the final operations capabilities of the PDSS, PPS, and PTC to support Flights 5A, 6A. Payload unique ICDs and verification plans were completed and Payload Integration Agreements were baselined.

An Operational Readiness Review (ORR) for the Telescience Support Center (TSC) was held at JSC. Crew training in the Ground Development Facility (GDF) will begin for activation of the rack on-orbit and human research experiments to be conducted, followed by start of training in the Hi Fidelity Mock-up. The Payload Checkout Unit (PRCU) facility mods were completed ahead of schedule and units were delivered to JSC, MSFC, GRC, and KSC.

During FY 1999, the first two EXPRESS Racks continued Assembly/Testing to support on-dock delivery to KSC in early 2000. Express Rack subsystem qualification was completed. Rack 1 Acceptance Testing was completed. The Active Rack Isolation ISS Characterization Experiment (ARIS ICE) continued preparation for launch on the second EXPRESS Rack. EXPRESS Rack trainer

units were delivered to the Payload Training Facility. These units will be used for procedure development and crew training to support the 6A and subsequent flights. Subsystem hardware integration and verification were completed. EXPRESS Racks 3, 4 and 5 continued in Fabrication/Assembly/Testing.

A PDR for the EXPRESS Pallet scheduled for FY 1999 was delayed because of Brazilian funding problems.

The Window Observational Research Facility (WORF) completed its Systems Requirements Review and PDR.

Utilization Support - FY 2000

Expedition 2 and 3 Crews will continue payload training to support Increments 2, 3 and 4. Certificate of Flight Readiness Reviews (COFR) will be conducted for payloads planned for 5A.1, 6A, and 7A.1.

Express Rack 2 Acceptance Testing will be completed and the first two EXPRESS Racks will be delivered to KSC for launch on 6A. Subrack payload integration of Racks 1 and 2 will occur at KSC. Delivery, final testing, and subrack integration for the second two EXPRESS Racks will be completed for launch on 7A.1. EXPRESS Racks 6, 7 and 8 will initiate Fabrication/Assembly/Testing.

The Express Pallet program will complete its PDR.

The Window Observational Research Facility will complete a CDR and initiate Fabrication/Assembly/Testing.

Utilization Support - FY 2001

The payload operations facilities will continue to support on-orbit payload operations. Payload crew training will continue to support Increments 4, 5 and 6. Payload Readiness Reviews will be conducted to support assembly flights 8A – 9A.1.

The first four EXPRESS Racks will be on-orbit and conducting payload operations. The fifth EXPRESS Racks will complete final integration testing and KSC processing for launch on UF-2. Express Racks 6, 7 and 8 will continue Fabrication/Assembly/Testing.

The Express Pallet Program will complete a CDR and initiate Fabrication/Assembly/Testing.

The Window Observational Research Facility will be delivered on-dock to KSC to complete integration testing and KSC processing to support launch on UF-2.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE STATION RUSSIAN PROGRAM ASSURANCE *

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Russian Program Assurance.....	203,000	200,000	300,000

* This assumes a $100M million reallocation from Vehicle funding in FY 1999 for Russian goods and services. NASA has not submitted to Congress the intended increase of $100 million for RPA for Operating Plan consideration, pending further discussions with Rosaviakosmos, the Russian Aeronautics and Space Agency. Currently, no payments are being made for Russian goods and services, pending appropriate resolution of Service Module delivery scheduling and Proton launch support.

PROGRAM GOALS

Russian Program Assurance (RPA) was established within the Space Station program to fund contingency activities and backup capabilities in response to concerns about the impact of potential delays or shortfalls in the Russian Government's ISS commitments. These concerns were heightened by the slippage of the Russian service module (SM) from May 1998 to December 1998, and then to the first quarter of FY 2000, with additional delays of at least four months due to recent Proton launch vehicle failures.

NASA's approach to contingency planning is to incrementally fund only those activities that permit the United States to continue to move forward should the planned contributions of our ISS partners not be delivered as scheduled, rather than to assume the responsibilities of other ISS partners. It is a process based on: 1) identification of risks; 2) development of contingency plans to reduce these risks; 3) establishment of decision milestones and the criteria by which action will be taken; and, 4) implementation of contingencies as necessary. The RPA funding provides contingency activities to address ISS program requirements resulting from potential delays or shortfalls on the part of Russia in meeting its commitments to the ISS program, allowing the U.S to move forward with ISS assembly or operations in spite of potential shortfalls. These contingency activities are not intended to protect against the complete loss of Russian contributions. That impact would cause an extended delay to the program, necessitating additional crew return, life support, reboost, and guidance and control capabilities to replace planned Russian contributions, and result in a significantly more costly and less robust space station.

BACKGROUND

For several years Russia has experienced significant economic challenges resulting in the Russian Aviation and Space Agency (Rosaviakosmos) receiving only a fraction of its approved budget. These shortfalls have resulted in schedule slips of the ISS

hardware and operations support that Russia was responsible for funding and providing. To accommodate this shortfall, the U.S. developed a three step contingency plan and initiated specific developments to protect the ISS schedule and capabilities in the event of further Russian delays or shortfalls. In spring 1997, NASA embarked on the initial steps of a contingency plan to provide U.S. capabilities to mitigate the impact of further Russian delays. Step one consisted primarily of the development of an Interim Control Module (ICM), built by the U.S. Naval Research Laboratory for NASA, to provide command, attitude control, and reboost functions to provide a backup capability in the event the Russian Service Module was significantly delayed or not successfully provided. Over the last year we have continued to see further delays on the Russian elements. Therefore, during summer 1998, NASA initiated activities to implement additional contingency plans to provide flexibility for the United States in the event of further Russian delays or shortfalls. These consist primarily of building a U.S. Propulsion Module, enhancing logistics capabilities, modifying the Shuttle fleet for enhanced Shuttle reboost of ISS, and procurement of needed Russian goods and services to support Russian schedules for the Service Module and early ISS Progress and Soyuz launches.

STRATEGY USED FOR ACHIEVING PROGRAM GOALS

During summer 1998, NASA undertook additional efforts to provide flexibility for the United States and our international partners in the event of further Russian delays. These efforts included initiation of development of an enhanced Shuttle reboost capability for the ISS. This capability will be obtained by modifying the Shuttle orbiters to permit the internal transfer of fuel from aft to forward tanks, so that the maximum amount of excess maneuvering propellant can be utilized by the Shuttle to reboost the ISS while it is docked. To further reduce U.S. reliance upon Russian contributions, NASA is proceeding with the development of a U.S. Propulsion Module that will provide permanent, independent reboost and attitude control. The Propulsion Module is being acquired from Boeing under the existing prime contract, and the development schedule calls for both the preliminary and critical design reviews to be completed in FY 2000.

In parallel to the development of the Propulsion Module, NASA has maintained a continuous dialogue with Rosaviakosmos representatives to fully understand their fiscal situation. The Administration and the Congress responded affirmatively to NASA's September 1998 recommendation to provide the Rosaviakosmos immediate funding to help ensure timely delivery of the critical Russian Service Module and to avoid costly delays in the first launches of ISS hardware. NASA entered into a contract with the Russian Aviation and Space Agency to secure valuable crew time to conduct U.S.-directed research, and procure critically needed research stowage space. This agreement, funded at $60 million, provided funds that allowed Rosaviakosmos to maintain delivery schedules for the Service Module and other early Russian contributions. With the Service Module approaching its launch date, NASA intends to shift the focus of work on the Interim Control Module (ICM) to an alternate contingency plan. If the Service Module launch is successful, then the ICM will be reconfigured to provide an on-orbit back-up capability for the Service Module, in the event that Russian Progress resupply missions are disrupted.

To ensure the continuation of ISS assembly, including certainty regarding availability of Russian Progress and Soyuz, NASA's contingency planning includes the possible purchase of additional needed goods and services from Russia. NASA has conducted discussions with Rosaviakosmos regarding the purchase of Soyuz crew return services as well as the purchase of other needed hardware and services such as trainer mock-ups, EVA suit support, a docking mechanism for the Propulsion Module, a pressure dome for the ICM, and additional test and validation efforts for U.S./Russian flight software. The purchase of Soyuz services would

enable deployment of six crew to orbit prior to the availability of a U.S. crew return capability. The baseline Russian commitment provides for Soyuz services for three crew. The deployment of six crew can be achieved with two Soyuz present on the ISS. The baseline of seven crew cannot be achieved without an operational U.S. crew return capability. These purchases would be provided with FY 1999 RPA funding being held for that purpose, pending resolution with Rosaviakosmos. Currently, no payments are being made for Russian goods and services, pending appropriate resolution of Service Module delivery scheduling and Proton launch support.

NASA believes that this approach - working with Russia to assure near-term critical capabilities while developing independent U.S. capabilities over the long-term - provides the best approach to address the impacts from the Russian economic situation. NASA may determine that adjustments to funding for ISS activities may be warranted subject to changes in conditions with Russia. NASA will be prepared to provide some of the logistics requirements that Russia agreed to provide, should Rosaviakosmos be unable to provide critical logistics needs due to insufficient funding from their government. This could require Shuttle logistics flights for dry cargo and reboost of the ISS stack, as well as the procurement of logistics carrier support until a permanent U.S. propulsion capability is delivered. The potential use of orbiter vehicle OV-102 to meet some of these logistics requirements requires the installation of a docking module. This requirement is also included in the current RPA budget request. The International Space Station Intergovernmental Agreement and the bilateral Memorandum of Understanding between NASA and Rosaviakosmos provide the flexibility to modify Russian participation in the ISS Program through a rebalancing of partner contributions and benefits.

There is an additional possibility for U.S. backup capabilities in this budget request, for development of alternate access to space. Funding for alternate access is provided in the Advanced Space Transportation program with the Science, Aeronautics, and Technology appropriation request, and could result in a U.S. capability other than the Space Shuttle, to provide logistics services. Such capabilities could be purchased as commercial services, and might not only provide contingency capability against potential shortfalls, but could also be used to add flexibility to Space Station operations.

SCHEDULE & OUTPUTS

SM Launch Plan: December 1998 Revised: 4th Qtr FY 1999 Revised: 1st Qtr FY 2000 Revised: 2nd Qtr FY 2000 Revised Target: 4th Qtr FY 2001	• The SM will be launched as part of the ISS Revision E Assembly Sequence
Interim Control Module Plan: February 1999 Revised: Contingency	• Complete environmental testing in the flight configuration (1st Qtr FY 2000) • Deliver ICM to KSC (3rd Qtr FY 2000 – contingent on launch of the Russian Service Module) • Launch ICM on Flight 2A.3 (contingent on launch of the Russian Service Module)

Propulsion Module Plan: 4th Qtr FY 2002 Revised Target: 2nd Qtr FY 2003	• Complete Preliminary Design Review (1st Qtr FY 2000) • Complete Critical Design Review (3rd Qtr FY 2000) • Start structural test article assembly (4th Qtr FY 2000) • Conduct thruster hot fire tests (1st Qtr FY 2001) • Mate aft and mid Propulsion Module segments (3rd Qtr FY 2001) • Propulsion Module on dock at KSC (2nd Qtr FY 2002) • Launch on Flight 10A.1 (2nd Qtr FY 2003)
Orbiter Interconnectivity Modifications Plan: 2nd Qtr FY 2001	• OV-103 modification complete (2nd Qtr FY 2001) • OV-105 modifications complete (3rd Qtr FY 2002)

ACCOMPLISHMENTS AND PLANS

FY 1999

RPA major activities included the completion of ICM development, continuation of work on orbiter fuel transfer modifications, and the initiation of Propulsion Module development. Activities accomplished include:

- ICM Shuttle Flight Definition Requirements approved in June 1999.
- ICM integrated flight configuration tests completed in September 1999.
- Propulsion Module System Requirements Review completed in April 1999.
- Propulsion Module/Shuttle Orbiter Propellant Transfer System Requirements Review completed in June 1999.
- Orbiter Interconnect Modification kit design completed in July 1999.

FY 2000

RPA Propulsion Module development will proceed at an accelerating pace. Depending on the results of the Russian Service Module launch, the ICM will be deployed either in its original configuration, or modified to provide a Service Module back-up capability. Initial procurements of Russian goods and services could start, along with the delivery of the first Orbiter interconnect modification kits. Specific activities include:

- ICM delivery to KSC for launch in response to Russian Service Module deployment.
- Propulsion Module Preliminary Design Review (1st Qtr FY 2000) and Critical Design Review (3rd Qtr FY 2000).
- Propulsion Module structural test article assembly (4th Qtr FY 2000).
- First installation of an Orbiter fuel interconnect mod kit (3rd Qtr FY 2000).
- Depending on the availability of Russian Progress vehicles, provisions may be made for U.S. resupply of pressurized logistics.

FY 2001

This year the Propulsion Module development will be nearing completion, the final delivery of Orbiter fuel interconnectivity mod kits will occur, and work on Russian goods and services will continue. Specific activities include:

- Conduct hot fire test of Propulsion Module thrusters (2nd Qtr FY 2001).
- Start final assembly and checkout of Propulsion Module flight segments (4th Qtr FY 2001).
- Complete delivery of Orbiter fuel transfer mod kits (3rd Qtr FY 2001).

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE STATION CREW RETURN VEHICLE

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Crew Return Vehicle	--	75,000	90,000

PROGRAM GOALS

The safety of the crew for the International Space Station is of critical importance. The Russian Soyuz provides a contingency capability for life threatening emergencies that may arise during extended stays on orbit on the Mir and will do so for the initial years of the ISS. Continued sole reliance on the Soyuz limits the crew size for the ISS and poses significant operational and programmatic risks. Each Soyuz can only transport a crew of three and has to be changed out after about six months on orbit. A more capable crew return vehicle that overcomes the limitations of the Soyuz is the most viable long-term approach for ensuring crew safety. A goal of the Crew Return Vehicle (CRV) project is to leverage the technologies, processes, test results, and designs developed in the preliminary technology development work carried out in the X-38 project and related contractor studies of a CRV.

The Phase 1 Crew Return Vehicle (CRV) project will initiate work towards an independent U.S. crew return capability for the ISS for the life of the Station. The CRV would accommodate safe return for up to seven crew under the following scenarios:

- Crew member(s) ill or injured while the space shuttle orbiter is not at the station
- Catastrophic failure of the station that makes it unable to support life and the space shuttle orbiter is not at the station or is unable to reach the station in the required time
- Problem with the space shuttle that makes it unavailable to re-supply the station or change-out crew in a required timeframe

STRATEGY FOR ACHIEVING GOALS

NASA has funded the X-38 project to reduce the risk of developing a CRV. The X-38 design has a strong foundation from the lifting body research and technology developments carried out since the 1960's. The transition from X-38 research and development to CRV design and development began in FY2000 as X-38 work phases out and CRV work phases in. The transition plan is as follows:

- Phase 0 - An unfunded observation period in which contractors interact with the X-38 project team. This effort began 20 July 1998 and will run through Final RFP release for Phase 1 in November 99. Five companies are currently participating in this phase, which is being performed with X-38 Advanced Projects funding.

- Phase 1 - Multiple contractors will perform delta design tasks to convert the X-38 design into an operational CRV design and participate in flight-testing. The X-38 space flight test is currently scheduled to occur in mid- FY 2002. At the end of Phase 1 (approximately 2 years) the final build-to-specification configuration of an X-38-based CRV will have been established. The government at the end of Phase 1 will own all drawings, prints, schematics, and software. The ISS CRV budget provides the funding for Phase 1 contractor activities in FY 2000-2002.
- Phase 2 - Currently planned as a production of four CRVs by industry. However, a decision on whether to proceed with an X-38-based CRV design will be made within two years, in the context of broader decisions that NASA and the Administration will make regarding future space transportation architectures. Funding for Phase 2 of CRV development currently resides in the SAT account, pending these decisions. Should the decision be made to proceed with the X-38-based CRV design, an amount up to the Phase 2 funds would be transferred from the SAT account, and a contractor would be selected by a competition based on the released drawings for the vehicle. In this case, Phase 2 funding is anticipated to be provided beginning in FY 2002.

These three phases will include three primary tasks:
- Perform delta design tasks necessary to convert the X-38 design into an operational CRV design, and perform necessary system integration internally and with STS and ISS.
- Perform atmospheric and space flight tests of X-38 prototype vehicles.
- Perform production of the CRV operational vehicles.

NASA plans to proceed with the completion of the X-38 Space Flight Test and the Phase 1 activities to maintain the CRV Program on a path intended to have a U.S. crew return capability on-orbit within approximately six months of the time the ISS achieves 6 person crew capability. During the period between achieving six person capability and the availability date of the U.S. crew return capability, NASA plans to use the Soyuz crew return services purchased from Russia (as described previously in the Russian Program Assurance budget justification) so that the ISS can operate at the six-person capability until the U.S. capability is available. When a U.S. crew return capability is available, and the habitation module is delivered, seven person crew capability will be achieved.

SCHEDULE & OUTPUTS

Start Contractor Observation period Plan: July 1998 Revised: Completed	Beginning of period in which potential contractors observe X-38 Program flight demonstration test and development activity.
CRV Request For Proposal release for Phase 1 Plan: March 1999 Actual: November 1999	Release RFP for a funded period in which two contractors will perform delta design tasks to convert the X-38 design in an operational CRV design and participate in flight-testing.

Phase 1 Start Plan: October 1999 Revised: 4th[rd] Qtr FY 2000	Multiple contractors will perform delta design tasks to convert the X-38 design in an operational CRV design and participate in flight-testing.
Design Freeze for Phase 2 RFP Plan: September 2000 Revised: TBD	Freeze CRV design based on X-38 experience to date and use for basis of CRV development contract.
Award CRV development contract (nominal case) Plan: December 2000 Revised: June 2002	Contractor Award of CRV development contract (Pending broader space transportation decisions within two years).

ACCOMPLISHMENTS AND PLANS

FY 1999

X-38 accomplishments are reported under Payload and Operations/Advanced Projects for FY 1999.

FY 2000 Plans

The X-38 program has been integrated into the Space station budget as part of the CRV program, as the transition from X-38 research and development to CRV design and development begins. Since the scope of the X-38 project objectives were significantly expanded to include early development of technologies directly usable on an operational CRV, the X-38 project will be merged into the CRV project as a part of the ISS Program. X-38 funding and milestones such as completion of CRV operational technology developments and the Vehicle 201 space flight test will continue to be tracked as an X-38 element of the CRV project, but will be accomplished in direct support of, and will be funded by, the CRV project. The CRV Request for Proposals (RFP) for CRV Phase 1 was issued with proposals due by February 20, 2000. The CRV Phase 1 contract will be awarded in the 4th quarter of FY 2000 and work will be initiated in that quarter of the fiscal year. The Memorandum of Understanding (MOU) between the European Space Agency (ESA) and NASA on CRV participation will be complete during FY 2000.

FY 2001 Plans

For FY 2001, the following provides an indication of the design and development work that will be conducted, using both civil servants and contractors.

CRV Vehicle Subsystems

NASA Tasks

Avionics work would include continued development of the CRV inertial guidance system (SIGI Space Integrated GPS/INS); avionics instrumentation; radiation-hardened computer system network elements; operating system software; and communication system signal processors. Flight dynamics work would include simulation-based development and verification of the CRV flight controls. Mechanisms work will include delivery of electro-mechanical actuators (EMAs) and laser pyros, and EMA testing. Parafoil work would continue with testing, new parafoil procurements, and integrated structural dynamic modeling. Thermal Protection System component procurement will continue.

Phase 1 Contractor Tasks

Contractor tasks would be focussed on designs of avionics computers, networks and data busses; instrumentation and sensors; electrical power system; communications system; engineering support; laser altimeter; data recorder; avionics testbed; human computer interface; flight software; and interconnect wiring and connectors. Mechanisms work will be performed on the berthing/docking design and fin mechanisms. Manufacturing work would begin on the berthing/docking module; metallic structural parts materials and machining; composite structural parts materials and manufacturing; and tooling. Structures work would begin on structural, hatch, window and couch design.

Systems Engineering and Operations

Safety, Reliability, and Quality Assurance, and Systems Engineering and Integration work would be performed as NASA primary tasks supported by the Phase 1 contractors

Operations tasks include analyses of CRV separation (from Space Station) dynamics, continuing development of landing site and site selection requirements, and development of crew displays and controls requirements. Mission operations tasks include Mission Control Center and facility design requirements, modeling, and development of flight and ground procedures and flight rules. Logistics and maintenance tasks would focus on development of a spares program. Kennedy Space Center tasks include development of launch support and logistics flight operations requirements.

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **SPACE SHUTTLE**

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Safety and Performance Upgrades	571,600	488,800	--	HSF 2-6
Shuttle Operations	2,426,700	2,490,700	--	HSF 2-21
Flight Hardware	--	--	2,005,900	HSF 2-27
Ground Operations	--	--	551,800	HSF 2-32
Flight Operations	--	--	273,600	HSF 2-35
Program Integration	--	--	334,400	HSF 2-38
(Safety Allocation including upgrades - non-add)	--	--	(256,400)	
Total	2,998,300	2,979,500	3,165,700	
Distribution of Program Amount by Installation				
Johnson Space Center	1,721,400	1,658,900	1,768,100	
Kennedy Space Center	173,300	185,800	222,600	
Marshall Space Flight Center	1,050,500	1,079,900	1,131,900	
Stennis Space Center	38,100	40,300	30,000	
Dryden Flight Research Center	4,600	4,800	4,800	
Ames Research Center	3,500	4,500	3,000	
Langley Research Center	200	200	200	
Glenn Research Center	200	0	0	
Goddard Space Flight Center	2,300	100	100	
Jet Propulsion Laboratory	300	0	0	
Headquarters	3,900	5,000	5,000	
Total	2,998,300	2,979,500	3,165,700	

Note: This FY 2001 Request is submitted in a restructured budget format for the Space Shuttle Program. Please see the Special Issues section for more details.

GENERAL

The Shuttle Operations program provides launch services to a diverse set of customers, supporting launch, on-orbit operations, and return to earth, of payloads that range from small hand-held experiments to large laboratories. While most missions are devoted to NASA-sponsored payloads, others including industry, partnerships, corporations, academia, national and international agencies exercise wide participation. NASA, and the U.S. and international scientific communities are beneficiaries of this approach. The Space Shuttle is a domestically and internationally sought-after research facility because of its unique ability to provide on-orbit crew operations, rendezvous/retrieval and payload provisions, including power, telemetry, pointing and active cooling.

The Space Shuttle continues to prove itself to be the most versatile launch vehicle ever built. This has been demonstrated by: (1) rendezvous missions with the Russian Space Station Mir; (2) advancing life sciences and technology through long-duration Spacelab and Spacehab missions; and (3) repairing and servicing the Hubble Space Telescope, enabling many new discoveries in Space Science. The Space Shuttle has also performed rescue and retrieval of spacecraft and has begun the assembly of the International Space Station. The Space Shuttle services numerous cooperative and reimbursable payloads involving foreign governments and international agencies. The focus of international cooperation, for which the Space Shuttle is uniquely suited, is the assembly and operational support of the International Space Station (ISS), already underway with the first ISS assembly mission, STS-88, successfully completed.

The Shuttle Operations program participates in the domestic commercial development of space, providing limited flight opportunities to NASA's Centers for Commercial Development of Space. These non-profit consortia of industry, academia and government were created to conduct commercially applied research activities by encouraging industry involvement leading to new products and services through access to the space environment. Cooperative activities with the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Defense (DoD) and other U.S. agencies are advancing knowledge of health, medicine, science and technology. Prime examples include Space Shuttle support for the flight of STS-95 in FY 1999 with Senator John Glenn, many cooperative NASA-NIH experiments and the Shuttle Radar Topography Mission, a joint DoD/NASA payload, now scheduled in FY 2000.

The restructuring activities of the past seven years have resulted in an annual funding reduction of about 30% from FY 1993 to FY 1999, and a 32% reduction in the shuttle workforce since FY 1992. In addition, after 96 successful missions, a significant reduction in operational requirements is continuing. Consolidation of contracts to a single prime contract is progressing successfully since the award of the Space Flight Operations Contract (SFOC) on October 1, 1996. Phase II of the transition is now underway, with the first production hardware contract (Solid Rocket Booster) transferred into SFOC in FY 1998. The remaining schedule for further transition is under review.

Continued safe operation of the Space Shuttle is a high priority, in particular to ensure the Space Shuttle's ability to support assembly and operations of the International Space Station. Investments in Shuttle safety improvements have been made over the last several years while, at the same time, the Shuttle budget was reduced by about a third through efficiencies and contract consolidation. Having achieved these reductions, continued improvements in Shuttle safety will require additional investment. Therefore, this request augments the NASA budget with investments that will continue to significantly improve safety and protect the nation's investment in the Station and Shuttle. There are two elements to the increase in Shuttle safety funding. First, the FY

2001 budget includes a $51 million increase in the Research and Program Management line of the Mission Support account for additional personnel at NASA's Human Space Flight centers to ensure that the right skills and staffing levels are in place to launch and assemble the Station. Second, a $256.4 million Safety Allocation is requested in the FY 2001 Space Shuttle budget to address Shuttle safety improvements through hardware/software upgrades, personnel, facility, or other investments. This is significant increase over $100 million per year for Shuttle upgrades that was in previous requests.

NASA will be conducting an external review to assess how the Safety Allocation funds can most effectively be used to improve the safety of the Space Shuttle. NASA will proceed with the three highest priority upgrade activities, and additional activities may be started pending results of the external review. The three highest priority upgrades include two with firm plans: the electric auxiliary power unit (EAPU), and advanced health monitoring for the Space Shuttle main engines (SSME). These two upgrades alone will improve Shuttle safety during ascent from the current 1 in 438 chance of catastrophic failure to 1 in 735. The third of the highest priority upgrades, which is still under study, is for improved avionics in the Shuttle cockpit. This will improve the situational awareness of the crew, and better equip them to handle potential flight anomalies. Additional upgrades will be assessed as part of the external review, and candidates include additional upgrades to the SSME, advanced thrust vector control for the solid rocket boosters, and others.

Space Shuttle safety investments are an important element of NASA's strategy for an overall Space Launch Initiative. These investments ensure continued safe Shuttle operations through this decade, and provide assurance that the Shuttle could operate into the next decade, if needed.

The Space Shuttle operations prime contractor, United Space Alliance, was awarded the Space Flight Operations Contract (SFOC) on October 1, 1996 based upon a phased approach to consolidate operations into a single prime contract for operational activities. The first phase began in late 1996 with 12 operational and facility contracts being consolidated from the majority of the effort previously conducted by Lockheed Martin and Boeing North American (the two corporations which comprise the USA joint venture). The second phase will add other operations work to the contract after the contractor has had an appropriate amount of time to evolve into its more responsible role in phase I. Transition will take another 1-2 years and employ approximately 7300 equivalent persons at steady state.. The specific schedule for all transitions is currently under review. The reasons for this phased approach are two-fold:

1. The ongoing major development projects will be completed.
2. The transition to the prime can occur at a more measured pace.

The roles and missions of the contractor and government relationships have been defined to ensure program priorities are maintained and goals are achieved. The SFOC contractor is responsible for flight, ground and mission operations of the Space Shuttle. The accountability of its actions and those of its subcontractors will be evaluated and incentivized through the use of a combined award/incentive fee structure of the performance-based contract. NASA, as owner of assets, customer of operations services and director of launch/flight operations, is responsible for (a) surveillance and audit to ensure compliance with SFOC requirements and (b) internal NASA functions. Further, NASA retains chairmanship of control boards and forums responsible for acceptance/rejection/waiver of Government requirements while the SFOC contractor is responsible for requirement

implementation. The SFOC contractor is required to document and maintain processes/controls necessary to ensure compliance with contract requirements and to sign a certification of flight readiness (CoFR) to that effect for each flight.

This FY 2001 Request is submitted in a restructured budget format for the Space Shuttle Program. There are several reasons why this new structure is beneficial. First and foremost, as the Program has become more operational in nature and undergone consolidation of its contracts into a single operational contract approach; the budget should reflect the way in which the Program is managed. The Space Shuttle Program is an operational effort, therefore, a structure consistent with the nature and maturity of the program is being implemented. Also, the four major budget elements of Flight Hardware, Ground Operations, Program Integration and Flight Operations are consistent with the Space Flight Operations Contract (SFOC) Work Breakdown Structure. This consistency improves NASA's ability to account for and reconcile the work accomplished and expenditures. Another benefit to the new structure is the old nomenclature, "Safety and Performance Upgrades" (S&PU), will no longer be used as a budgetary naming convention. The new structure provides much more clarity with the Upgrades activity and recent augmentations included in this request. The S&PU as a budget category included many other items in addition to Upgrades, which led to confusion as to what were and were not considered upgrades. Under the new structure, upgrades are clearly delineated under each of the four line items.

PROGRAM GOALS

The primary goals of the Shuttle Operations program in priority order are: (1) fly safely; (2) meet the flight manifest; (3) improve supportability and (4) improve the system.

NASA policy planning assumes the Space Shuttle will need to be capable of supporting the critical transportation requirements for at least the next decade including the assembly of the Space Station and Space Station operations. In order to maintain a viable human transportation capability that will operate into this new century and support NASA's launch requirements, specific program investments are required. These investments are consistent with NASA's strategy of ensuring the Space Shuttle remains viable until a new transportation system is operational.

STRATEGY FOR ACHIEVING GOALS

All decisions regarding program requirements, programmatic changes and budget reductions are guided by the program's goals as stated above. Three key elements of this budget request are: (1) the continued transition to a single prime contractor for space flight operations; (2) continuation of safety and supportability upgrades; and (3) Orbital Maintenance Down Periods (OMDPs) to be conducted at Palmdale, California.

The overall strategy for the Shuttle Operations budget is to request funding levels sufficient to allow the Space Flight Operations Contract to meet the intended flight rates. This includes appropriate contingency planning in both budget and schedule allowances to assure transportation and assembly support to the Space Station program. At the same time it also incentivizes the contractor to identify opportunities for reductions in operations costs while still ensuring the safe and reliable operation of the Space Shuttle. The continued transition of activities to the Space Flight Operations Contract represents a key element of this strategy.

This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years. Although FY 1999 had only four flights and six flights are planned for FY 2000, FY 2001 is a nine-flight year and includes seven International Space Station (ISS) assembly and utilization flights, the remainder of the third Hubble Space Telescope servicing mission and a dedicated microgravity research mission. The flight rate is anticipated to continue at 8 to 9 per year through FY 2004 without any significant increase in this budget. This manifest supports the Nation's science and technology objectives through scheduled science missions and continued assembly of the ISS.

In addition to flying safely, restructuring the program and conducting a single prime consolidation, we are completing activities that have been in the Safety and Performance Upgrades program, and transitioning to a new budget structure which integrates safety and supportability upgrades into the four major budget elements. The Shuttle Operations program's strategy for the Safety and Performance Upgrades budget has been to fund those modifications and improvements which will provide for the safe, continuous and affordable operations of the Space Shuttle system for the foreseeable future. This is an essential element of the launch strategy required for continuing supportability to the ISS. Completion of selected projects, termed "Phase I" upgrades, has improved Space Shuttle safety and payload-to-orbit performance by 13,000 pounds. The additional payload-to-orbit performance allows the Shuttle to achieve the orbital inclination and altitude of the International Space Station. The largest of these projects was the Super Light Weight Tank (SLWT) which was successfully flown on STS-91. All Phase I upgrades are complete and have met the performance requirements of the first Space Station assembly flight, STS-88, in the 1st quarter of FY 1999.

In the Space Shuttle's FY 1999 Congressional request, the Agency had formed a Space Transportation Council (STC) to assess advanced transportation areas in both the Office of Space Flight and the Office of Aeronautics and Space Transportation Technology. In recognition of the value of close collaboration on the technology needs of future reusable launch vehicles, lead responsibility has been consolidated within the Space Transportation Technology program. The Space Transportation Council will provide management oversight and policy direction across the agency's activities in this area. Potential major Shuttle upgrades will be examined under the Future Space Launch industry-led trade studies described in the Space Transportation Technology section. These studies will provide the basis for decisions by NASA and the Administration on pursuing a future operational launch strategy to purchase launch services from privately owned and operated launch systems, to further reduce NASA's launch costs.

This budget also includes Supportability upgrades to develop systems, which will combat obsolescence of vehicle and ground systems in order to maintain the program's viability into this new century. Vendor loss, aging components, high failure rates of older components, high repair costs of Shuttle-specific devices and negative environmental impacts of some outdated technologies are areas to be addressed.

This budget provides funds required for modifying and improving the capability of the Space Shuttle to ensure its viability as a safe, effective transportation system and scientific platform. It also addresses increasingly stringent environmental requirements, obsolescence of subsystems in the flight vehicle and on the ground and capital investments needed to achieve reductions in operational costs. The Block IIA engines flew on STS-89 in January of 1998. Work continues on the Alternate Fuel Turbopump for the planned introduction of the Block II Space Shuttle Main Engine (SSME) in FY 2000.

BASIS OF FY 2001 FUNDING REQUIREMENT

SAFETY AND PERFORMANCE UPGRADES

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Orbiter improvements	234,800	183,700	--
Multifunction-electronic display system	9,800	--	--
Other orbiter improvements	188,300	105,200	--
Upgrades	36,700	78,500	--
Propulsion upgrades	175,700	213,200	--
Space shuttle main engine upgrades	167,200	151,100	--
[Alternate Turbopump program]	[56,900]	[41,300]	[--]
[Large Throat Main Combustion Chamber]	[6,500]	[1,400]	[--]
[Phase II+ Powerhead Retrofit]	[4,500]	[2,700]	[--]
[Other main engine upgrades]	[99,300]	[105,700]	[--]
Solid rocket booster improvements	2,600	1,900	--
Super Lightweight tank	1,100	500	--
Upgrades	4,800	59,700	--
Flight operations & launch site equipment upgrades	147,600	80,900	--
Flight operation upgrades	46,100	29,600	--
Launch site equipment upgrades	48,000	2,700	--
Upgrades	53,500	48,600	--
[Checkout and Launch Control System] [included above]	[50,000]	[39,800]	[--]
[Other Upgrades] [included above]	[3,500]	[8,800]	[--]
Construction of Facilities	13,500	11,000	--
Total	571,600	488,800	--

GENERAL

The Safety and Performance Upgrade program is measured by the success it has in accomplishing the ongoing projects consistent with approved schedule and cost planning and also the effect these projects have on the overall operation of the Space Shuttle System. Success depends on developing these projects and getting them implemented to help ensure the Space Shuttle's safe operation and improving the reliability of the supporting elements.

This FY 2001 Request is submitted in a restructured budget format for the Space Shuttle Program. The old nomenclature, "Safety and Performance Upgrades" (S&PU), will no longer be used as a budgetary naming convention. The new structure provides much more clarity with the Upgrades activity and recent augmentations included in this request. The S&PU as a budget category included many other items in addition to Upgrades, which led to confusion as to what were and were not considered upgrades. Under the new structure, upgrades are clearly delineated under each of the four line items of Flight Hardware, Ground Operations, Program Integration and Flight Operations.

The following is a brief description of these activities.

Orbiter Improvements

The Orbiter improvements program provides for enhancements of the Space Shuttle systems, produces space components that are less susceptible to damage and maintains core skills and capabilities required to modify and maintain the Orbiter as a safe and effective transportation and science platform. These activities are provided by Boeing Reusable Space Systems (as a major subcontractor to United Space Alliance (USA)) in two major locations: the Huntington Beach, California facility provides engineering support; and the Palmdale, California operation provides Orbiter Maintenance Down Period (OMDP) support as discussed below, as well as manufacturing and testing. Other activities that support this effort are subsystem management engineering and analysis conducted by Lockheed-Martin Corporation and development and modifications required for support to the extravehicular capability conducted by Hamilton Sundstrand.

An Orbiter Maintenance Down Period (OMDP) occurs when an Orbiter is taken out of service periodically for detailed structural inspections and thorough testing of its systems before returning to operational status. This period also provides opportunities for major modifications and upgrades, especially those upgrades that are necessary for improving performance to meet the International Space Station operational profile.

Propulsion Upgrades

The main engine safety and performance upgrade program is managed by the Marshall Space Flight Center (MSFC) and supports the Orbiter fleet with flight-qualified main engine components and the necessary engineering and manufacturing capability to address any failure or anomaly quickly. The Rocketdyne Division of Boeing Reusable Space Systems is responsible for operating three locations that provide engine manufacturing, major overhaul, components recycle and test. They are:

(1) Canoga Park, California which manufactures and performs major overhaul to the main engines;

(2) Stennis Space Center (SSC), Mississippi for conducting engine development, acceptance and certification tests; and
(3) Kennedy Space Center (KSC), Florida where the engine inspection checkout activities are accomplished at the KSC engine shop.

Engine ground test and flight data evaluation, hardware anomaly reviews and anomaly resolution are managed by the Marshall Space Flight Center (MSFC). The Alternate Turbopump project is also managed by the MSFC under contract with Pratt Whitney of West Palm Beach, FL.

Flight Operations and Launch Site Equipment Upgrades

The major flight operations facilities at Johnson Space Center (JSC) include the Mission Control Center (MCC), the flight and ground support training facilities, the flight design systems and the training aircraft fleet that includes the Space Shuttle Training aircraft and the T-38 aircraft.

The major launch site operational facilities at KSC include three Orbiter Processing Facilities (OPFs), two launch pads, the Vehicle Assembly Building (VAB), the Launch Control Center (LCC) and three Mobile Launcher Platforms (MLPs). The most significant upgrade in this account is the Checkout and Launch Control System (CLCS) at KSC.

Construction of Facilities

Construction of Facilities (CofF) funding for Space Shuttle projects is provided in this budget to refurbish, modify, reclaim, replace and restore facilities at Office of Space Flight Centers to improve performance, address environmental concerns of the older facilities and to ensure their readiness to support the Space Shuttle Operations.

PROGRAM GOALS

NASA policy planning assumes the Space Shuttle will need to be capable of supporting the critical transportation requirements for at least the next decade including the assembly of the Space Station and Space Station operations. In order to maintain a viable human transportation capability that will operate into this new century and support NASA's launch requirements, specific program investments are required. These investments are consistent with NASA's strategy of ensuring the Space Shuttle remains viable until a new transportation system is operational.

STRATEGY FOR ACHIEVING GOALS

This budget provides funds required to modify and improve the capability of the Space Shuttle to ensure its viability as a safe, effective transportation system and scientific platform. It also addresses increasingly stringent environmental requirements, obsolescence of subsystems in the flight vehicle and on the ground and capital investments needed to achieve reductions in operational costs. The Block IIA engines flew on STS-89 in January of 1998. Work continues on the Alternate Fuel Turbopump for the planned introduction of the Block II Space Shuttle Main Engine (SSME) in FY 2000.

SCHEDULES AND OUTPUTS

The Safety and Performance Upgrade program is measured by the success it has in accomplishing the ongoing projects consistent with approved schedule and cost planning. Success depends on developing/implementing these projects to help ensure the Space Shuttle's safe operation, improving the performance and reliability of the supporting elements and improving efficiencies to reduce operational costs. This budget addresses all elements of the Space Shuttle program and is managed through an approval process that ensures that new projects are evaluated, approved and initiated on a priority basis and that existing projects meet established cost and schedule goals. Significant milestones are listed below:

Orbiter Improvements

Multifunction Electronic-Display System (MEDS) - MEDS is a state-of-the-art integrated display system that will replace the current Orbiter cockpit displays with an integrated liquid crystal display system.

MEDS Initial Operational Capability (IOC) Plan: 2nd Qtr FY 1999 Revised: 2nd Qtr FY 2000	First flight of a MEDS equipped Orbiter. (OV-104/STS-101)

Global Positioning System (GPS) - GPS will replace the current TACAN navigational system in the Orbiter navigation system when the military TACAN ground stations will be phased out. The planned readiness date for the Space Shuttle's system is FY 2001.

Orbiter Install Complete Plan: 4th Qtr FY 1998 Revised: 2nd Qtr FY 1999	Installation and checkout of hardware on OV-104 at Palmdale.
Complete GPS operational Capability Plan: Under Assessment	Initial operation of GPS without TACAN system. (Under Assessment.)

Orbiter Maintenance Down Periods/Orbiter Major Modification (OMDP/OMM)

Initiate Columbia (OV-102) OMDP Plan: 3rd Qtr FY 1999 Revised: 4th Qtr FY 1999	Conduct routine maintenance and structural inspection. Also, install the MEDS upgrade, hardware for 3-string GPS capability and OV-102 scarring mods.

Initiate Discovery (OV-103) OMDP Plan: 3rd Qtr FY 2000 Revised: 1st Qtr FY 2002	Conduct routine maintenance and structural inspection. Also, install the MEDS upgrade, hardware for 3-string GPS capability.

Propulsion Upgrades

Space Shuttle Main Engine Safety Improvements - Introduction of the Block I and Block II changes into the Space Shuttle's Main Engine (SSME) program will improve the SSME margin of safety by a factor of two. The interim Block IIA configuration (Block II without the ATP High-Pressure Fuel Turbo Pump (HPFTP)) implements the safety and performance margins provided by the Large Throat Main Combustion Chamber (LTMCC) while the HPFTP development problems are solved.

High Pressure Fuel Turbopump CDR Plan: 3rd Qtr FY 1996 Revised: 3rd Qtr FY 1998	Completion of Critical Design Review (CDR) will allow production to proceed for implementation of the Alternate Turbopump high pressure fuel pump into the Block II Engine upgrade. Revised due to design delays
First flight of Block II engine Plan: 4th Qtr FY 1997 Revised: 1st Qtr FY 1998 Revised: 4th Qtr FY 2000	The high pressure fuel turbopump will be combined with the LTMCC and previous Block I upgrades. Revised due to testing delays

Flight Operations and Launch Site Equipment Upgrades- Upgrades to the Mission Control Center were completed in FY 1998 period which improved operations reliability and maintainability and also took advantage of the state-of-the-art technology in displays and controls. In addition, upgrades continued in FY 1998 to the Launch Site Equipment at KSC, which will increase reliability and reduce obsolescence.

CLCS "Atlas" Delivery Plan: 2nd Qtr FY 1999 Actual: 1st Qtr FY 2000	The Atlas delivery represents the first fully operational delivery for the project. This delivery will allow the start of usage of a CLCS set of hardware, system software and application software for processing of Space Shuttle components in the Hypergolic Maintenance facility at KSC.
SAIL set installation Plan: 2nd Qtr FY 1999 Actual: 3rd Qtr FY 1999	The CLCS Shuttle Avionics Integration Lab (SAIL) set completed facility modifications and hardware installation and activation. This set will be used to validate CLCS application software against real flight-like hardware.
First Launch Using CLCS Plan: Under review	Launch the first Shuttle from a CLCS - equipped Launch Control Center.

Complete Migration of CLCS to all Firing Rooms and Simulators Plan: Under review	CLCS fully operational for flight support. This will result in a significant reduction in operating cost, up to 50%, of the current Launch Processing System.

Space Shuttle Safety Upgrades - New upgrades are being initiated by the Space Shuttle program to help ensure continued safe operations of the Space Shuttle by improving the margin of safety. The dates are planning estimates rather than commitments, as the program is still in an early definitional phase, but all new Space Shuttle safety upgrades will be fully in place on the Shuttle fleet by FY 2005. The Space Shuttle program is in the process of developing detailed project plans.

Electric Auxiliary Power Unit (APU) – Orbiter - Battery powered electric motors will replace turbines powered by hydrazine, a highly flammable and environmentally hazardous fluid. The turbines are used to drive the hydraulic pumps providing control for the orbiter such as engine movement, steering, and braking functions. The upgrade eliminates hydrazine leakage/fire hazards, eliminates turbine overspeed hazards, and reduces toxic materials processing hazards.

Electric APU Start
Plan: 4th Qtr FY 1999
Actual: 4th Qtr FY 1999

Space Shuttle Main Engine (SSME) Advanced Health Monitoring (AHM) - Another new safety upgrade, this project entails a suite of instrumentation, software, and computational capabilities for real-time engine assessment, rapid turnaround, and reduction in invasive, manual processing and testing. The system includes vibration monitoring, engine performance monitoring, engine exhaust plume analysis, and overall health analysis. It consists of two phases; Phase I reduces pump failures, Phase II mitigates engine.

SSME AHM Phase I Start
Plan: 1st Qtr FY 2000
Actual: 1st Qtr FY 2000

SSME AHM Phase I
Preliminary Design Review
Plan: 3rd Qtr FY 2000

SSME AHM Phase I Critical Design Review Plan: 4th Qtr FY 2000	Completion of Critical Design Review will allow drawings to be released for production to proceed.

SSME AHM Phase II Start
Plan: 2nd Qtr FY 2000

Avionics/Cockpit/Safety Implementation - This new safety upgrade improves crew situational awareness and reduces flight crew workload. It provides automated control of complex procedures and increases the level of flight crew autonomy. Functional capabilities include enhanced Caution & Warning (a system to monitor critical instrumentation parameters), abort situation monitoring and trajectory assessment, improved integrated vehicle instrumentation displays, Remote Manipulator System (RMS) safety enhancements for the robotic arm, and rendezvous and proximity operations.

Avionics/Cockpit Start
Plan: 1st Qtr FY 2000
Actual: 1st Qtr FY 2000

Construction of Facilities

Complete Phase I Restore Firex Pumps and Piping at LC-39 Plan: 3rd Qtr FY 1999 Actual: 4th Qtr FY 1999	Restoration is needed. Pumps are currently inadequate to provide spray coverage during an emergency. This project replaces underrated firex loop piping and components, and provides fire protection for the Orbiter Mid-Body Umbilical Unit (OMBUU) at Pads A and B. Additional work was necessary to complete the associated controls, including control cable installation and termination on Pad B. Final work scheduled to be complete during Pad A modification period in FY 1999.
Complete Phase II Restore Firex Pumps and Piping at LC-39 Plan: 3rd Qtr FY 1999 Revised: 2nd Qtr FY 2000	Restoration is needed. Pumps are currently inadequate to provide spray coverage during an emergency. This project removes and replaces existing Firex pumps, motors, refurbishes diesels, and installs a new underground pipe between the pump station and Pads A and B. Delayed due to scope and funding transfer from KSC to JSC/SFOC to complete project.
Rehabilitation of 480V Electrical Distribution System at MAF	External Tank manufacturing building Rehabilitation of the 480V Electrical Distribution System is a 4 phase project. Each phase will be implemented in the main manufacturing areas of building 103. Project Phasing and scope for each phase:
Complete Phase I Plan: 2nd Qtr. FY 1999 Actual:	Phase I, Final Assembly Area Project will upgrade the power distribution system from below the substation to the respective tools (labor-intensive project working over flight hardware).
Complete Phase II Plan: 1st Qtr. FY 2000 Actual: 1st Qtr. FY 2000	Phase II, ET Sub-Assembly Area Project will upgrade the power distribution system from below the substation to the respective tools.

Start Phase III Plan: 1st Qtr. FY 1999 Actual: 1st Qtr. FY 1999	Phase III, Substations Nos. 17A/17B will replace the core system, Transformers and switch gear, breakers and oil switches. Include some down stream cable, cable tray and panel upgrades. Planned completion date is 1st Quarter FY 2001.
Start Phase IV Plan: 1st Qtr. FY 2000	Phase IV, Substations Numbers, 7B, 4 & 5 - core system, transformers and switch gear, breakers and oil switches. Planned completion date is 2nd Quarter FY 2001.
Complete Pad B Chiller Replacement at LC-39 Plan: 2nd Qtr. FY 99 Actual: 3rd Qtr. FY 99	This project replaces the aged facility chillers at Launch Complex 39, Pad B, and reconfigures the system for more efficient maintenance.
Complete Rehabilitation of High Pressure Industrial Water System at SSC Plan: 2nd Qtr. FY 99 Actual: 2nd Qtr. FY 99	This project initiates the restoration of the High Pressure Industrial Water Plant to ensure system reliability in support of the Space Shuttle Main Engine testing.
Restoration of Pad A PCR Wall and Ceiling Integrity at LC-39 Start Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99 Complete Plan: 1st Qtr. FY 00 Actual:	This project provides for repair and replacement of damaged PCR wall Panels (Sides 1, 2, 3, & 4), replacement or elimination of deteriorated and leaking access doors and other needed replacement and restoration. The modification will eliminate degrading flexducts and filter housings, improve pressurization of the PCR, provide an even distribution of airflow and provide safe personnel access for maintenance and repair.
Pad A Surface and Slope Restoration at LC-39 Start Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99 Completion Plan: 1st Qtr. FY 00 Actual:	This project provides for repair of the Pad A surface concrete, pad slopes and the crawlerway grid path.

Start Repair of Pad A Flame Deflector & Trench at LC-39 Start Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99	This project provides for repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members and repair/replacement of bricks in the Flame Trench wall.
Complete Repair of Pad A Flame Deflector & Trench at LC-39 Plan: 1st Qtr. FY 2000 Revised: 4th Qtr. FY 2000	This project provides for repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members, and repair/replacement of bricks in the Flame Trench wall.
Start Pad A FSS Elevator restoration at LC-39 Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99	This project modifies the elevator structural on Pad A and refurbishes the elevator cabs, cables and cableway.
Complete Pad A FSS Elevator restoration at LC-39 Plan: 1st Qtr. FY 00 Actual: 1st. Qtr. FY 00	This project modifies the elevator structure on Pad A, and refurbishes the elevator cabs, cables and cableway.
Start Pad B Surface and Slope Restoration at LC-39 Plan: 2nd Qtr. FY 2000 Actual: 1st Qtr. FY 99	This project provides for repair of the Pad B surface concrete, pad slopes and the crawlerway grid path.
Cell E Restoration Start Plan: 3rd Qtr FY 99 Actual: 3rd Qtr FY 99	This project restores and modifies the common solution return systems and lining for the cell. The cell lining is breaking down and requires restoration work at Michoud Assembly Facility.
Towway Support (Phase II) Start Plan: 2nd Qtr. FY 99 Actual: 2nd Qtr. FY 99	This project is the SSP portion of the Support Facility at the Towway of the SLF. This project will refurbish the SLF Convoy Operation's capability at the SLF. Scheduled for completion in the 4th Quarter of FY 2000.

Start VAB and Crawlerway Modification, LC-39 (Safe Haven) Start: Plan: 4th Qtr. FY 99 Actual: 4th Qtr. FY 99	This project restores the crawlerway into VAB highbay 2 and provides an Orbiter towway into Highbay 4. Partial stack access will be provided for in Highbay 2 and Orbiter storage and access will be provided for in Highbay 4. This will allow use of the VAB highbays as a safe haven during hurricanes, allow for additional manifest flexibility for stacking operations and Orbiter access operations to continue when Highbay 1 and 3 contain full stacks.
Start Repair VAB Elevator Controls Plan: 2nd Qtr. FY 00	This Project replaces the elevator systems in the Vehicle Assembly Building. The controls, cabs and cableway systems are obsolete and parts are no longer available. A recent fire in one of the VAB elevator controls caused a concern with the safety of the systems. This was identified as a safety project.

ACCOMPLISHMENTS AND PLANS

A significant portion of the Safety and Performance Upgrades (S&PU) budget has been dedicated to preventing the deleterious and costly effects of obsolescence, especially at a time when the program is undertaking the challenge of reducing the costs of operations. This portion of the budget contains projects that impact every element of the Space Shuttle vehicle. The S&PU budget supports replacing Tactical Airborne Navigation System (TACAN) with Global Positioning System (GPS), upgrading the T-38 aircraft with maintainable systems, replacing elements of the launch site complex, upgrading major elements of the training facilities at Johnson Space Center, testing of main engine components at Stennis Space Center, testing of Orbiter reaction control systems at the White Sands Test Facility and replacing critical subsystems in the Kennedy Space Center facility complex.

The Space Shuttle program rationale for supportability upgrades is founded on the premise that safety, reliability and mission supportability improvements must be made in the Shuttle system to continue to provide safe and affordable operations into the next century. These will enable safe and efficient Shuttle operations during the Space Station era while providing a robust testbed for advanced technologies and a variety of customers.

The Space Shuttle Upgrade activity is planned and implemented from a system-wide perspective. Individual upgrades are integrated and prioritized across all flight and ground systems, ensuring that the upgrade is compatible with the entire program and other improvements. Selection of new upgrades through the review process approved by the Associate Administrator for Space Flight, the Program Management Council (PMC) and the Administrator is utilized. Space Shuttle upgrades are developed and implemented in a phased manner supporting one or more of the following program goals:

- Improve Space Shuttle system safety and/or reliability
- Support the Space Shuttle program manifest/Space Station
- Improve Space Shuttle system support

The phasing strategy is coordinated with the Reusable Launch Vehicle (RLV) project management and other development projects to capture common technology developments while meeting the Shuttle manifest.

Safety

Micrometeoroid Protection (discussed more thoroughly in Orbiter Upgrades, below)

- isolation valves for the radiator cooling loops to increase orbiter survivability
- "armoring" the radiator panels
- putting additional thermal protection on the wing leading edges to make them more damage tolerant

Orbiter Improvements

The Space Shuttle Program performs hundreds of modifications throughout the year related to design changes to improve reliability, supportability, or meet new program requirements. These changes are a result of hardware failures or design enhancements identified through ground checkouts or in-flight. Additional orbiter modifications are approved as the International Space Station development advances and risk mitigation options are identified and implemented. The modifications are implemented either during a standard orbiter processing flow at Kennedy Space Center in Florida or during Orbiter Maintenance Down Period at Palmdale, California.

OV-102 has just entered into its major modification and structural inspection at NASA's Palmdale facilities. The major modification to be performed this period are the installation of the multifunctional electronics display system and the scar for a three string global positioning system.

To increase the space shuttle weight to orbit performance in support of International Space Station flights, the space shuttle program implemented a variety of orbiter weight reduction modifications. The project consisted of converting a variety of orbiter hardware from aluminum to composite or fabric structure. The components that were redesigned included the Lithium hydroxide rack assembly, the middeck pallets, middeck lockers and their associated trays, the middeck accommodations rack, and the tool stowage assembly. The approximate total orbiter weight reduction is 600 to 700 pounds pending the number of pallets flown. All of the above mentioned hardware has been delivered and has supported missions with the exception of the second and third shipset of lockers which will be delivered in early calendar year 2000.

Other miscellaneous modifications completed throughout the year include the delivery of 322 redesigned remote power controllers (RPC's) to replace the existing obsolete RPC's, 100 mission certification of the 17 inch external tank and orbiter disconnect, delivery of the redesigned extravehicular mobility unit battery chargers and the delivery of 13 shipsets of external tank disconnects.

Propulsion Upgrades

The most complex components of the Space Shuttle Main Engine (SSME) are the high pressure turbopumps. Engine system requirements result in pump discharge pressure levels from 6000 to 8000 psi and turbine inlet temperatures of 2000 Degrees F. In reviewing the most critical items on the SSME that could result in a catastrophic failure, 14 of the top 25 are associated with the turbopumps. The current pumps' dependence on extensive inspection to assure safety of flight have made them difficult to produce and costly to maintain. The Alternate Turbopump Program (ATP) contract with Pratt & Whitney was signed in December 1986 and called for parallel development of both the High Pressure Oxidizer Turbopump (HPOTP) and the High Pressure Fuel Turbopump (HPFTP) to correct the shortcomings of the existing high pressure turbopumps. This objective is achieved by: utilizing design, analytical and manufacturing technology not available during development of the original components; application of lessons learned from the original SSME development program; elimination of failure modes from the design; implementation of a build-to-print fabrication and assembly process; full inspection capability by design and demonstrated design reliability through increased fleet leader testing. The turbopumps utilize precision castings, reducing the total number of welds in the pumps from 769 to 7. Turbine blades, bearings and rotor stiffness are all improved through the use of new materials and manufacturing techniques. The SSME upgrades will expand existing safety margins and reduce operational costs.

The SSME Powerhead is the structural backbone of the engine. The Phase II+ Powerhead has reduced the number of welds, improving producibility and reliability.

The heat exchanger uses the hot turbine discharge gases to convert liquid oxygen in a thin walled coil to gaseous oxygen for pressurization of the external oxygen tank. The current heat exchanger coil has seven welds exposed to the hot gas environment. A small leak in one of these welds would result in catastrophic failure. The new Single Coil Heat Exchanger eliminated all seven critical welds and tripled the wall thickness.

The Large Throat Main Combustion Chamber (LTMCC) first flight was on STS-89 (January 1998) and resulted in lower pressures and temperatures throughout the engine system thereby increasing the overall Space Shuttle system flight safety and reliability. The wider throat area accommodates additional cooling channels. Consequently, hot gas wall temperatures are significantly reduced increasing chamber life. The LTMCC design also incorporated new fabrication techniques to reduce the number of critical welds and improve the producibility of the chamber.

The development and production of the powerhead, heat exchanger and LTMCC are all being performed under contract with the Rocketdyne division of Boeing Reusable Space Systems.

The "block" change concept for incorporating changes into the main engine was introduced and baselined during FY 1994. The Phase II+ Powerhead, the Single Coil Heat Exchanger and the new high pressure oxidizer turbopump comprise Block I. This change was introduced and flown for the first time in July 1995. The Block IIA configuration fielding the LTMCC was successfully flown in January 1988 on STS-89. The Block II is scheduled to be flown in FY 2000 and incorporates the alternate high pressure fuel turbopump with the Block IIA design. The end result of these engine improvements is an increase in the overall engine durability,

reliability and safety margin and producibility. This is consistent with NASA's goals of decreasing failure probability and reducing Space Shuttle costs.

Increased safety margins and launch reliability on the Space Shuttle will also be realized through the implementation of new sensors (temperature, pressure and flow) for use in the SSME. SSME history has shown that the engine is more reliable than the instrumentation system; however, a transducer failure could result in a flight scrub or on-pad abort, failure to detect an engine fault, or an in-flight abort. These sensor upgrades have been completed and have been essential to improving the reliability of the Space Shuttle's launch capability.

The Solid Rocket Booster also received several upgrades designed to reduce the expense of recovering and refurbishing the boosters. Those upgrades include a saltwater activated mechanism to release the parachutes (full implementation STS-95), improvements to the parachutes themselves and a modification to the aft skirt brackets.

Flight Operations and Launch Site Equipment Upgrades

These upgrades support pre-launch and post-launch processing of the four Orbiter fleet. Key enhancements funded in launch site equipment include: replacement hydraulic pumping units that provide power to Orbiter flight systems during ground processing; replacement of 16-year old ground cooling units that support all Orbiter power-on testing; replacement of communications and tracking Ku-band radar test set for the labs in the Orbiter Processing Facility and High Bays that supports rendezvous capability and the missions; communications and instrumentation equipment modernization projects that cover the digital operational intercom system, major portions of KSC's 17-year old radio system and the operational television system; improvement of the Space Shuttle operations data network that supports interconnectivity between Shuttle facilities and other KSC and off-site networks; replacement storage tanks and vessels for the propellants, pressurants and gases; an improved hazardous gas detection system; and fiber optic cabling and equipment upgrades.

A new Checkout and Launch Control System (CLCS) was approved for development at KSC in FY 1997. The CLCS will upgrade the Shuttle launch control room systems with state-of-the-art commercial equipment and software in a phased manner to allow the existing flight schedule to be maintained. The CLCS will reduce operations and maintenance costs associated with the launch control room by as much as 50% and will provide the building blocks to support future vehicle control system requirements. The Juno and Redstone phases of the CLCS were delivered in FY 1997. In these phases, the initial integration platform was defined, the engineering platform was installed and the interface with the math models was established. The Thor delivery was completed in FY 1998. During this phase, initial ground data bus interfaces were established and the system software was ported to the production platforms. The Atlas delivery in FY 1999 provided support for the initial applications for the Orbiter Processing Facility, the final applications for the Hypergolic Maintenance Facility, the math model validation, an interface to the Shuttle Avionics Integration Lab (SAIL) and hardware testing for SAIL. The Titan delivery will provide support for completion of development and the start of validation testing for application software used for shuttle orbiter power up testing. The Scout phase of CLCS is planned to support operational use in the Orbiter Processing Facility and development of Pad and launch related application software. The Delta and Saturn phases include the completion of all launch application development, completion of software certification and validation and a complete integrated flow demonstration. Since the FY 1999 Budget, software independent validation and verification (IV&V) performed by Ames Research Center was also added to this project. By the end of FY 2002, Operations Control Room-1 will be fully

operational, followed by certification. The first Shuttle launch using the CLCS is scheduled for FY 2002 with full implementation to be completed one year later.

The Hardware Interface Modules (HIM), which are electrical command distribution systems that support the launch processing system (LPS) at KSC are over 25 years old and have experienced an increased failure rate and higher cost of repair over the past several years. The HIM upgrade replaces all chassis and cards with state-of-the-art "off the shelf" hardware to improve system reliability and maintainability. Production and installation should be complete in FY 2000.

Modernization of the Operational Television System (OTV) is based upon a phased engineering design and implementation strategy, which should enhance and automate the visual surveillance capability at KSC. A key element of the plan includes the design of a camera control system beginning in FY 1996 through FY 2000 which allow the installation of new digital video cameras and their associated elements with minimal impact to operations. Other key elements of the design approach, beginning in FY 1997 are the phased transition to a high bandwidth digital switch, switched digital recording, integrated monitoring stations and a high priority subset of CCD cameras, utilizing a unified control over the entire television environment. Continual efforts have been underway since the project started in FY 1995, in order to phase out existing tube cameras with new CCD cameras, provide functional camera station control and record capability to the new Operations Control Rooms, sustain existing firing room support and replace obsolete switching and recording hardware.

Construction of Facilities (CoF)

FY 1999 CoF funding provided for improvements for facilities at KSC and MAF. At KSC, there are two projects which are both at Launch Complex Pad A - the restoration of the Fixed Support Structure Elevator System and the repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members, and repair/replacement of bricks in the Flame Trench wall. At MAF, there are two projects Phase III of IV for the rehabilitation of the 480-volt electrical distribution system and Repair Cell E Common solution return and lining.

FY 2000 CoF funding will provide for improvements for facilities at KSC, MAF and SSC. At KSC there are 3 projects which complete the Towway convoy support restoration, repair Pad B Surface and Slope areas and repair the VAB elevators. The SSC project begins the rehabilitation of the A-2 Test Stand for Shuttle Testing and completes the MAF 480V Electrical distribution Rehab. For additional details on these projects, please refer to the <u>Mission Support - Construction of Facilities</u> budget.

BASIS OF FY 2001 FUNDING REQUIREMENT

SHUTTLE OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Orbiter and integration	608,000	698,800	--
Propulsion	1,071,200	1,053,100	--
[External tank]	[363,200]	[355,200]	[--]
[Space shuttle main engine]	[200,000]	[187,500]	[--]
[Reusable solid rocket motor]	[339,000]	[356,700]	[--]
[Solid rocket booster]	[169,000]	[153,700]	[--]
Mission and launch operations	747,500	738,800	--
Total	2,426,700	2,490,700	--

GENERAL

Space Shuttle operations requirements are met through a combination of funds received from Congressional appropriations and reimbursements received from customers whose payloads are manifested on the Space Shuttle. The reimbursements are applied consistent with the receipt of funds and mission lead times and is subject to revision as changes to the manifest occur. The FY 1999 reimbursements totaled $35.9 million. The FY 2000 reimbursements are assumed to be $23.2 million. The majority of FY 1999 and FY 2000 reimbursements are due to the Shuttle Radar Topography Mission. These standard service reimbursements offset the total budget for the Space Shuttle and have been assumed in the NASA direct funding requirements identified.

The Space Shuttle operations budget includes sustaining engineering, hardware and software production, logistics, flight and ground operations and flight crew operations for all elements while continuing to pursue environmentally necessary operations and manufacturing improvements. The single, prime contract is the Space Flight Operations Contract (SFOC) held by United Space Alliance comprising one-half of the Operations budget. As development items are completed, additional effort will be transitioned into SFOC.

P.L. 106-74 includes a limitation stipulating that $40 million of the amount provided for Human Space Flight "shall be available to the space shuttle program only for preparations necessary to carry out a life and micro-gravity science mission, to be flown between STS-107 and December 2001." The amounts earmarked within the FY 2000 Shuttle budget ($40 million) and amounts available in the FY 1999 appropriation for Life and Microgravity Sciences and Applications ($10 million) fall considerably short of the funds needed to conduct a science mission, which ranges $137-166 million. A page on this issue is in the Special Issue Section.

This FY 2001 Request is submitted in a restructured budget format for the Space Shuttle Program. There are several reasons why this new structure is beneficial. First and foremost, as the Program has become more operational in nature and undergone

consolidation of its contracts into a single operational contract approach; the budget should reflect the way in which the Program is managed. The Space Shuttle Program is an operational effort, therefore, a budget structure consistent with the nature and maturity of the Program is being implemented. Also, the four major budget elements of Flight Hardware, Ground Operations, Program Integration and Flight Operations are consistent with the Space Flight Operations Contract (SFOC) Work Breakdown Structure. This consistency improves NASA's ability to account for and reconcile the work accomplished and expenditures.

Orbiter and Integration

The Orbiter project element consists of the following items and activities:

(1) Orbiter logistics: spares for the replenishment of Line Replacement Units (LRUs) and Shop Replacement Units (SRUs) along with the workforce required to support the program; procurement of liquid propellants and gases for launch and base support;
(2) Production of External Tank (ET) disconnect hardware;
(3) Flight crew equipment processing as well as flight crew equipment spares and maintenance, including hardware to support Space Shuttle extravehicular activity;
(4) The sustaining engineering associated with flight software and the Orbiter vehicles;
(5) Various Orbiter support hardware items such as Pyrotechnic-Initiated Controllers (PICs), NASA Standard Initiators (NSI's) and overhauls and repairs associated with the Remote Manipulator System (RMS); and

The major contractors for these Orbiter activities are United Space Alliance for operations; and Hamilton Sundstrand for extravehicular mobility unit (EMU) operations.

Other support requirements are also provided for in this budget, including tasks which support flight software development and verification. The software activities include development, formulation and verification of the guidance, targeting and navigation systems software in the Orbiter.

System integration includes those elements managed by the Space Shuttle Program Office at the Johnson Space Center (JSC) and conducted primarily by United Space Alliance, including payload integration into the Space Shuttle and systems integration of the flight hardware elements through all phases of flight. Payload integration provides for the engineering analysis needed to ensure that various payloads can be assembled and integrated to form a viable and safe cargo for each Space Shuttle mission. Systems integration includes the necessary mechanical, aerodynamic and avionics engineering tasks to ensure that the launch vehicle can be safely launched, fly a safe ascent trajectory, achieve planned performance and descend to a safe landing. In addition, funding is provided for multi-program support at JSC.

Propulsion

External Tanks are produced by Lockheed Martin Corporation in the Government-Owned/Contractor-Operated (GOCO) facility near New Orleans, LA. This activity involves the following:

(1) Procurement of materials and components from vendors;
(2) Engineering and manufacturing personnel and necessary environmental manufacturing improvements.
(3) Support personnel and other costs to operate the GOCO facility; and
(4) Sustaining engineering for flight support and anomaly resolution.

The program began delivering Super Lightweight Tanks to KSC in support of the performance enhancement goal required by the Space Station in FY 1998. Only recurring costs associated with the Super Lightweight Tank are included in this account. Non-recurring costs are accounted for in the Safety and Performance Upgrades budget. The transition of the External Tank contract into Phase II SFOC is currently under review. .

The Space Shuttle Main Engine (SSME) operations budget provides for overhaul and repair of main engine components, procurement of main engine spare parts and main engine flight support and anomaly resolution. In addition, this budget includes funding to the Department of Defense for Defense Contract Management Command (DCMC) support in the quality assurance and inspection of Space Shuttle hardware and funds for transportation and logistics costs in support of SSME flight operations. Rocketdyne, a division of Boeing Reusable Space Systems, provides the bulk of the engine components for flight as well as sustaining engineering, integration and processing of the SSME for flight.

The Solid Rocket Booster (SRB) project supports:

(1) Procurement of hardware and materials needed to support the flight schedule;
(2) Work at various locations throughout the country for the repair of flown components;
(3) Workforce at the prime contractor facility for integration of both used and new components into a forward and an aft assembly; and
(4) Sustaining engineering for flight support.

USA is the prime contractor on the SRB and conducts SRB retrieval, refurbishment and processing at KSC.

The Reusable Solid Rocket Motor (RSRM) project has Thiokol of Brigham City, Utah as the prime contractor for this effort. This activity involves the following:

(1) Purchase of solid rocket propellant and other materials to manufacture motors and nozzle elements.
(2) Workforce to repair and refurbish flown rocket case segments, assemble individual case segments into casting segments and other production operations including shipment to the launch site;
(3) Engineering personnel required for flight support and anomaly resolution; and
(4) New hardware to support the flight schedule required as a result of attrition.

Mission and Launch Operations

Launch and Landing Operations provides the workforce and materials to process and prepare the Space Shuttle flight hardware elements for launch as they flow through the processing facilities at the Kennedy Space Center (KSC). The primary contractor is United Space Alliance. This category also funds standard processing and preparation of payloads as they are integrated into the Orbiter. It also provides for support to landing operations at KSC (primary), Dryden Flight Research Center (back-up) and contingency sites.

Operation of the launch and landing facilities and equipment at KSC involves refurbishing the Orbiter, stacking and mating of the flight hardware elements into a launch vehicle configuration, verifying the launch configuration and operating the launch processing system prior to lift-off. Launch operations also provides for booster retrieval operations, configuration control, logistics, transportation, inventory management and other launch support services. This element also provides funds for:

(1) Maintaining and repairing the Shuttle Data Center, which supports Space Shuttle processing as an on-line element of the Checkout and Launch Control System;
(2) Space Shuttle-related data management functions such as work control and test procedures;
(3) Purchase of equipment, supplies and services; and
(4) Operations support functions including propellant processing, life support systems maintenance, railroad maintenance, pressure vessel certification, Space Shuttle landing facility upkeep, range support and equipment modifications.

Mission and Crew Operations include a wide variety of pre-flight planning, crew training, operations control activities, flight crew operations support, aircraft maintenance and operations and life sciences operations support. The primary contractor is USA. The planning activities range from the development of operational concepts and techniques to the creation of detailed systems operational procedures and checklists. Tasks include:

(1) Flight planning;
(2) Preparing systems and software handbooks;
(3) Defining flight rules;
(4) Creating detailed crew activity plans and procedures;
(5) Updating network system requirements for each flight;
(6) Contributing to planning for the selection and operation of Space Shuttle payloads; and
(7) Preparation and plans for International Space Station assembly.

Also included are the Mission Control Center (MCC), Integrated Training Facility (ITF), Integrated Planning System (IPS) and the Software Production Facility (SPF). Except for the SPF (Space Shuttle only), these facilities integrate the mission operations requirements for both the Space Shuttle and International Space Station. Flight planning encompasses flight design, flight analysis and software activities. Both conceptual and operational flight profiles are designed for each flight and the designers also help to develop crew training simulations and flight techniques. In addition, the flight designers must develop unique, flight-dependent data for each mission. The data are stored in erasable memories located in the Orbiter, ITF Space Shuttle mission simulators and MCC computer systems. Mission operations funding also provides for the maintenance and operation of critical mission support

facilities including the MCC, ITF, IPS and SPF. Finally, Mission and Crew Operations include maintenance and operations of aircraft needed for flight training and crew proficiency requirements.

PROGRAM GOALS

The goal of Space Shuttle Operations is to provide safe, reliable and effective access to space. This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years. Although FY 1999 had only four flights and six flights are planned for FY 2000, FY 2001 is a nine flight year and includes the third Hubble Space Telescope servicing mission. The flight rate is anticipated to continue at 8 to 9 per year through FY 2004 without any significant increase in this budget. This represents a net increase of one flight during this time period from previous submissions. This manifest supports the Nation's science and technology objectives through scheduled Spacehab and other science missions and commencement of assembly of the International Space Station.

STRATEGY FOR ACHIEVING GOALS

Since FY 1992, cost reduction efforts have been successful in identifying and implementing program efficiencies and specific content reductions. Space Shuttle project offices and contractors have been challenged to meet reduced budget targets.

United Space Alliance was awarded the Space Flight Operations Contract (SFOC) on October 1, 1996. It includes a phased approach to consolidating operations into a single prime contract for operational activities. The first phase began in late 1996 with 12 operational and facility contracts being consolidated from the majority of the effort previously conducted by Lockheed Martin and Boeing North American (the two corporations which comprise the USA joint venture). The second phase will add other operations work to the contract after the contractor has had an appropriate amount of time to evolve into its more responsible role in phase I. Transition will take another 1-2 years and employ approximately 7300 equivalent persons at steady state.. The specific schedule for all transitions is currently under review. The reasons for this phased approach are two-fold:

1. The ongoing major development projects will be completed.
2. The transition to the prime can occur at a more measured pace.

The roles and missions of the contractor and government relationships have been defined to ensure program priorities are maintained and goals are achieved. The SFOC contractor is responsible for flight, ground and mission operations of the Space Shuttle. The accountability of its actions and those of its subcontractors will be evaluated and incentivized through the use of a combined award/incentive fee structure of the performance-based contract. NASA as owner of assets, customer of operations services and director of launch/flight operations, is responsible for (a) surveillance and audit to ensure compliance with SFOC requirements and (b) internal NASA functions. Further, NASA retains chairmanship of control boards and forums responsible for acceptance/rejection/waiver of Government requirements while the SFOC contractor is responsible for requirement implementation. The SFOC contractor is required to document and maintain processes/controls necessary to ensure compliance with contract requirements and to sign a certification of flight readiness (CoFR) to that effect for each flight.

SCHEDULES AND OUTPUTS

Since the Space Shuttle program has both an operational and development component, performance measures related to the Space Shuttle program reflect a number of different activities ranging from missions planned and time on-orbit in Shuttle Operations, to development milestones planned for the Safety and Performance Upgrades program. The following sets of diverse metrics can be utilized to assess overall program performance.

	FY 1999		FY 2000		FY 2001
Operations Metrics	Plan	Actual	Plan	Revised	Plan
Number of Space Shuttle Flights	6	4	8	6	[9]
Shuttle Operations Workforce (Prime Contractor (equivalent personnel))		13,800		13,353	[13,045]
Space Shuttle Processing Overtime Required	3%	3%	3%	3%	--
Number of Days On-orbit	59	36	80	61	[202]
Number of Primary Payloads Flown	6	4	8	6	[11]

Space Shuttle Missions and Primary Payloads

FY 1999		Plan	Actual/Revised
STS-95/Discovery	Hubble Orbital System Test (HOST)/Spacehab	October 1998	October 1998
STS-88/Endeavour	Space Station #1 (Node 1) (ISS-01-2A)	July 1998	December 1998
STS-93/Columbia	AXAF-Chandra	3rd Qtr FY 1999	July 1999
STS-96/Discovery	Space Station #2 Spacehab Cargo Module (ISS-02-2A.1)	3rd Qtr FY 1999	May 1999
STS-101/Atlantis	Space Station #3 (Spacehab Cargo Module (ISS-03-2A.2)	4th Qtr FY 1999	March 2000
STS-99/Endeavour	Shuttle Radar Topography Mission (SRTM)	4th Qtr FY 1999	January 2000

FY 2000		Plan	Actual/Revised
STS-103/Discovery	Hubble Space Telescope (HST) Servicing Mission 3A	--	December 1999
STS-92/Discovery	Space Station #4 (ITS-Z1) (ISS-04-3A)	1st Qtr FY 2000	June 2000
STS-97/Atlantis	Space Station #5 (PV Module) (ISS-05-4A)	1st Qtr FY 2000	July 2000
STS-98/Endeavour	Space Station #6 (US Lab) (ISS-06-5A)	2nd Qtr FY 2000	August 2000
STS-102/Discovery	Space Station #7 (MPLM-IP-01) (ISS-07-5A.1)	2nd Qtr FY 2000	October 2000
STS-100/Endeavour	Space Station #8 (MPLM-2P-01) (ISS-08-6A)	3rd Qtr FY 2000	November 2000
STS-104/Atlantis	Space Station #9 – Airlock (ISS-09-7A)	4th Qtr FY 2000	February 2001
STS-108/Columbia	Hubble Space Telescope (HST) Servicing Mission 3B	4th Qtr FY 2000	May 2001
STS-105/Atlantis	Space Station #10 (MPLM-IP-02) (ISS-10-7A.1)	4th Qtr FY 2000	March 2001

ACCOMPLISHMENTS AND PLANS

In FY 1999, the Space Shuttle launched four flights successfully including the first ISS assembly mission. This mission (STS-88) joined together the Russia built FCB module with the US built Unity node. Additional flights included one re-supply flight to the ISS and one microgravity research mission, which included the return to space of Senator John Glenn. Lastly, STS-93 successfully deployed another "great observatory" when it launched the Chandra – Advanced X-Ray Astrophysics Facility (AXAF).

The six flights manifested in FY 2000 include the emergency Hubble Space Telescope (HST) Servicing Mission 3A which will replace failing gyros on the HST and the Shuttle Radar Topography Mission (SRTM), a joint DOD/NASA payload to study the earth. The Space Shuttle will also visit the International Space Station four more times, for both assembly and maintenance. The first crew will begin the permanent occupation and presence aboard the ISS.

The Shuttle program has provided launch support for space science missions accommodating universities and industry as a space laboratory and technology research vehicle. Beginning in FY 1999, its primary mission is to support the on-orbit assembly and operations of the International Space Station. The Shuttle is also the only U.S. vehicle that provides human transportation to and from orbit. In FY 1999, 25 crewmembers flew approximately 230 days. In FY 2000, 41 crewmembers are planned to fly approximately 536 days.

BASIS OF FY 2001 FUNDING REQUIREMENT

FLIGHT HARDWARE

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
External Tank Production	[364,300]	[355,700]	349,700
Space Shuttle Main Engine Production	[281,500]	[302,000]	243,300
Space Shuttle Main Engine Test Support	[31,000]	[27,000]	19,900
Reusable Solid Rocket Motor	[341,600]	[358,600]	418,300
Solid Rocket Booster	[170,000]	[153,700]	137,500
Vehicle and EVA	[645,200]	[550,300]	625,800
Flight Hardware Upgrades	[34,800]	[137,300]	211,400
(Safety allocation including upgrades - non-add)			(211,400)
Total	[1,868,400]	[1,884,600]	2,005,900

PROGRAM GOALS

The goal of Flight Hardware programs to produce and maintain the various components of the Space Shuttle vehicles and provide for the upgrades required for safe, reliable and effective access to space.

STRATEGY FOR ACHIEVING GOALS

The Flight Hardware program contain many of the elements previously budgeted in the Space Shuttle Operations budget under Orbiter and Integration and Propulsion Operations, along with work previously budgeted in Safety and Performance Upgrades in Orbiter Improvements and Propulsion Upgrades.

The Flight Hardware program provides for enhancements of the Space Shuttle and produces space components that are not susceptible to damage and maintains core skills and capabilities required modifying and maintaining the Orbiter as a safe and effective transportation and science platform. These activities are provided by Boeing Reusable Space Systems (as a major subcontractor to United Space Alliance (USA)) in two major locations: the Huntington Beach, California facility provides engineering support; the Palmdale, California operation provides Orbiter Maintenance Down Period (OMDP) support as discussed below, as well as manufacturing and testing. Other activities that support this effort are subsystem management engineering and analysis conducted by Lockheed-Martin Corporation and development and modifications required for support to the extravehicular capability conducted by Hamilton Sundstrand.

The Flight Hardware program performs hundreds of modifications throughout the year related to design changes to improve reliability, supportability, or meet new program requirements. These changes are a result of hardware failures or design

enhancements identified through ground checkouts or in-flight. Additional Orbiter modifications are approved as the International Space Station development advances and risk mitigation options are identified and implemented. The modifications are implemented either during a standard Orbiter processing flow at Kennedy Space Center in Florida or during Orbiter Maintenance Down Period at Palmdale, California.

Orbiter Maintenance Down Periods (OMDPs) occurs when an Orbiter is taken out of service periodically for detailed structural inspections and thorough testing of its systems before returning to operational status. This period also provides opportunities for major modifications and upgrades, especially those upgrades that are necessary for improving performance to meet the International Space Station operational profile.

The Main Engine Program is managed by the Marshall Space Flight Center (MSFC) and supports the Orbiter fleet with flight-qualified main engine components and the necessary engineering and manufacturing capability to address any failure or anomaly quickly. The Rocketdyne Division of Boeing Reusable Space Systems is responsible for operating three locations that provide engine manufacturing, major overhaul, components recycle and test. They are:

(1) Canoga Park, California which manufactures and performs major overhaul to the main engines;
(2) Stennis Space Center (SSC), Mississippi for conducting engine development, acceptance and certification tests; and
(3) Kennedy Space Center (KSC), Florida where the engine inspection checkout activities are accomplished at the KSC engine shop.

The Marshall Space Flight Center (MSFC) manages engine ground test and flight data evaluation, hardware anomaly reviews and anomaly resolution. The Alternate Turbopump project is also managed by the MSFC under contract with Pratt Whitney of West Palm Beach, FL.

A Safety Allocation is requested in FY 2001 to address Shuttle safety improvements through hardware/software upgrades, personnel, facility, or other investments. This is significant increase over $100 million per year for Shuttle upgrades that was in previous requests. NASA will be conducting an external review to assess how the Safety Allocation funds can most effectively be used to improve the safety of the Space Shuttle. NASA will proceed with the three highest priority upgrade activities, and additional activities may be started pending results of the external review. The three highest priority upgrades are all part of the Flight Hardware budget element, and include two with firm plans: the electric auxiliary power unit (EAPU), and advanced health monitoring for the Space Shuttle main engines (SSME). These two upgrades alone will improve Shuttle safety during ascent from the current 1 in 438 chance of catastrophic failure to 1 in 735. The third of the highest priority upgrades, which is still under study, is for improved avionics in the Shuttle cockpit. This will improve the situational awareness of the crew, and better equip them to handle potential flight anomalies. Additional upgrades will be assessed as part of the external review, and candidates include additional upgrades to the SSME, advanced thrust vector control for the solid rocket boosters, and others. Pending results of the external review, and prior to commitment on specific additional investments, the unspecified Safety Allocation funding is kept under Flight Hardware, although it may shift to other Space Shuttle budget elements after investment decisions are made.

SCHEDULES AND OUTPUTS

Global Positioning System (GPS) - GPS will replace the current TACAN navigational system in the Orbiter navigation system when the military TACAN ground stations will be phased out. The planned readiness date for the Space Shuttle's system is FY 2001.

TACAN Removal Plan: 1st Qtr FY 2002	Select flights will be flown with both systems until the GPS flight hardware is certified.

Orbiter Maintenance Down Periods/Orbiter Major Modification (OMDP/OMM)

Initiate Discovery (OV-103) OMDP Plan: 3rd Qtr FY 2000 Revised: 1st Qtr FY 2002	Conduct routine maintenance and structural inspection. Also, install the MEDS upgrade, hardware for 3-string GPS capability.

Space Shuttle Safety Allocation - New upgrades are being initiated by the Space Shuttle program to help ensure continued safe operations of the Space Shuttle by improving the margin of safety. The dates are planning estimates rather than commitments, as the program is still in an early definitional phase, but all new Space Shuttle safety upgrades will be fully in place on the Shuttle fleet by FY 2005. The Space Shuttle program is in the process of developing detailed project plans.

Electric Auxiliary Power Unit (APU) - Orbiter –Battery powered electric motors will replace turbines powered by hydrazine, a highly flammable and environmentally hazardous fluid. The turbines are used to drive the hydraulic pumps providing control for the orbiter such as engine movement, steering, and braking functions. The upgrade eliminates hydrazine leakage/fire hazards, eliminates turbine overspeed hazards, and reduces toxic materials processing hazards

Electric APU Preliminary Design Review Plan: 3rd Qtr FY 2001	
Electric APU Critical Design Review Plan: 2nd Qtr FY 2002	Completion of Critical Design Review will allow drawings to be released for production to proceed.
Electric APU first flight Plan: 1st Qtr FY 2005	

Space Shuttle Main Engine (SSME) Advanced Health Monitoring (AHM) – Another new safety upgrade, this project entails a suite of instrumentation, software, and computational capabilities for real-time engine assessment, rapid turnaround, and reduction in invasive, manual processing and testing. The system includes vibration monitoring, engine performance monitoring, engine exhaust plume analysis, and overall health analysis. It consists of two phases; Phase I reduces pump failures, Phase II mitigates engine

SSME AHM Phase I first flight
Plan: 3rd Qtr FY 2003

SSME AHM Phase II
Preliminary Design Review
Plan: 1st Qtr FY 2002

SSME AHM II Critical Design Review
Plan: 4th Qtr FY 2002

Completion of Critical Design Review will allow drawings to be released for production to proceed.

SSME AHM II first flight
Plan: 1st Qtr FY 2005

Avionics/Cockpit/Safety Implementation – This new safety upgrade improves crew situational awareness and reduces flight crew workload. It provides automated control of complex procedures and increases the level of flight crew autonomy. Functional capabilities include enhanced Caution & Warning (a system to monitor critical instrumentation parameters), abort situation monitoring and trajectory assessment, improved integrated vehicle instrumentation displays, Remote Manipulator System (RMS) safety enhancements for the robotic arm, and rendezvous and proximity operations.

Avionics/Cockpit Preliminary
Design Review
Plan: 4th Qtr FY 2001

Avionics/Cockpit Critical Design Review
Plan: 4th Qtr FY 2002

Completion of Critical Design Review will allow drawings to be released for production to proceed.

ACCOMPLISHMENTS AND PLANS

OV-102 has just entered into its major modification and structural inspection at NASA's Palmdale facilities. The major modifications to be performed this period are the installation of the multifunctional electronics display system and the scar for a three-string global positioning system. Additionally, this Orbiter will undergo an extensive wiring inspection with repairs as needed.

To increase the Space Shuttle weight to orbit performance in support of International Space Station flights, the Shuttle Operations program implemented a variety of Orbiter weight-reduction modifications. The project consisted of converting a variety of Orbiter hardware from aluminum to composite or fabric structure. The components that were redesigned included the Lithium hydroxide rack assembly, the middeck pallets, middeck lockers and their associated trays, the middeck accommodations rack, and the tool stowage assembly. The approximate total Orbiter weight reduction is 600 to 700 pounds pending the number of pallets flown. All of the above-mentioned hardware has been delivered and has supported missions with the exception of the second and third shipset of lockers, which will be delivered in early calendar year 2000.

Other miscellaneous modifications completed throughout the year include the delivery of 322 redesigned remote power controllers (RPC's) to replace the existing obsolete RPC's, 100 mission certification of the 17-inch external tank and Orbiter disconnect, delivery of the redesigned extravehicular mobility unit battery chargers and the delivery of 13 shipsets of external tank disconnects.

BASIS OF FY 2001 FUNDING REQUIREMENT

GROUND OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Launch and Landing Operations	[548,100]	[506,400]	550,800
Checkout and Launch Control System (CLCS)	(50,000)	(39,800)	(40,000)
Ground Operations Upgrades	[1,000]	[8,800]	1,000
(Safety allocation including upgrades - non-add)			(41,000)
Total	[549,100]	[510,300]	551,800

PROGRAM GOALS

The goal of Ground Operations is to provide safe, reliable and effective access to space. This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years

STRATEGY FOR ACHIEIVING GOALS

The Ground Operations budget was previously funded in Shuttle Operations under Mission and Flight Operations and in Safety and Performance Upgrades in the Flight Operations and Launch Site Equipment upgrades.

The Ground Operations comprises most of the launch site operational facilities at KSC and their required upgrades. The major launch site operational facilities at KSC include three Orbiter Processing Facilities (OPFs), two launch pads, the Vehicle Assembly Building (VAB), the Launch Control Center (LCC) and three Mobile Launcher Platforms (MLPs). The most significant upgrade in this account is the Checkout and Launch Control System (CLCS) at KSC.

The Hardware Interface Modules (HIM), which are electrical command distribution systems that support the launch processing system (LPS) at KSC, are over 25 years old and have experienced an increased failure rate and higher cost of repair over the past several years. The HIM upgrade replaces all chassis and cards with state-of-the-art "off-the-shelf" hardware to improve system reliability and maintainability. Production and installation should be complete in FY 2000.

Modernization of the Operational Television System (OTV) is based upon a phased engineering design and implementation strategy, which should enhance and automate the visual surveillance capability at KSC. A key element of the plan includes the design of a camera control system beginning in FY 1996 through FY 2000 which allow the installation of new digital video cameras and their associated elements with minimal impact to operations. Other key elements of the design approach, beginning in FY 1997, are the phased transition to a high bandwidth digital switch, switched digital recording, integrated monitoring stations and a high priority subset of CCD cameras, utilizing a unified control over the entire television environment. Continual effort over the life span of the

project, FY 1995 to FY 2004, to phase out existing tube cameras with new CCD cameras, provide functional camera station control and record capability to the new Operations Control Rooms, sustain existing firing room support and replace obsolete switching and recording hardware.

The Complex Control System (CCS) is used to monitor and control processing and institutional facilities systems at KSC. The obsolescence of the current CCS makes it difficult and costly to incorporate new measurements and control points as new facilities are built or existing ones are upgraded. CCS infrastructure conversion is scheduled for completion in FY 2001.

Radio Frequency (RF) communications modernization replaces the existing KSC radio communications system with a combination of digital and conventional mobile, portable and fixed stations and associated off-the-shelf equipment. RF communications modernization is scheduled for completion in FY 2001.

A new Checkout and Launch Control System (CLCS) was approved for development at KSC in FY 1997. The CLCS will upgrade the Shuttle launch control room systems with state-of-the-art commercial equipment and software in a phased manner to allow the existing flight schedule to be maintained. The CLCS will reduce operations and maintenance costs associated with the launch control room by as much as 50% and will provide the building blocks to support future vehicle control system requirements.

These upgrades support pre-launch and post-launch processing of the four-Orbiter fleet. Key enhancements funded in launch site equipment include: replacement of hydraulic pumping units that provide power to Orbiter flight systems during ground processing; replacement of 16-year old ground cooling units that support all Orbiter power-on testing; replacement of communications and tracking Ku-band radar test set for the labs in the Orbiter Processing Facility and High Bays that supports rendezvous capability and the missions; communications and instrumentation equipment modernization projects that cover the digital operational intercom system, major portions of KSC's 17-year old radio system and the operational television system; improvement of the Shuttle Operations data network that supports interconnectivity between Shuttle facilities and other KSC and off-site networks; replacement storage tanks and vessels for the propellants, pressurants and gases; an improved hazardous gas detection system; and fiber optic cabling and equipment upgrades.

The Titan delivery will provide support for completion of development and the start of validation testing for application software used for Shuttle Orbiter power up testing. The Scout phase of CLCS is planned to support operational use in the Orbiter Processing Facility and development of Pad and launch-related application software. The Delta and Saturn phases include the completion of all launch application development, completion of software certification and validation and a complete integrated flow demonstration.

SCHEDULES AND OUTPUTS

First Launch Using CLCS Plan: Under review	Launch the first Shuttle from a CLCS - equipped Launch Control Center.
Complete Migration of CLCS to all Firing Rooms and Simulators Plan: Under review	CLCS fully operational for flight support. This will result in a significant reduction in operating cost, up to 50%, of the current Launch Processing System.

ACCOMPLISHMENTS AND PLANS

The Juno and Redstone phases of the CLCS were delivered in FY 1997. In these phases, the initial integration platform was defined, the engineering platform was installed and the interface with the math models was established. The Thor delivery was completed in FY 1998. During this phase, initial ground data bus interfaces were established and the system software was ported to the production platforms. The Atlas delivery in FY 1999 provided support for the initial applications for the Orbiter Processing Facility, the final applications for the Hypergolic Maintenance Facility, the math model validation, an interface to the Shuttle Avionics Integration Lab (SAIL) and hardware testing for SAIL. Since the FY 1999 Budget, software independent validation and verification (IV&V) performed by Ames Research Center was also added to this project. By the end of FY 2002, Operations Control Room-1 will be fully operational, followed by certification. The first Shuttle launch using the CLCS is scheduled for FY 2002 with full implementation to be completed one year later.

BASIS OF FY 2001 FUNDING REQUIREMENT

FLIGHT OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Mission Operations	[222,300]	[188,400]	203,500
Flight Crew Operations	[55,400]	[48,300]	62,300
Space and Life Sciences Operations	[6,600]	[7,900]	7,800
Flight Operations Upgrades	[2,500]	[--]	--
Total	[286,800]	[244,600]	273,600

PROGRAM GOALS

The goal of Flights Operations is to provide those services required for safe, reliable and effective access to space and to conduct on-orbit operations. This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years. Although FY 1999 had only four flights and six flights are planned for FY 2000, FY 2001 is a nine-flight year and includes the third Hubble Space Telescope servicing mission. The flight rate is anticipated to continue at 8 to 9 per year through FY 2004 without any significant increase in this budget. Also, this manifest supports the Nation's science and technology objectives through scheduled Spacehab and other science missions and continuation of assembly of the International Space Station.

STRATEGY FOR ACHIEVING GOALS

The Flight Operations budget was previously funded in Shuttle Operations under Mission and Flight Operations and in Safety and Performance Upgrades in the Flight Operations and Launch Site Equipment upgrades.

Flight Operations include a wide variety of pre-flight planning, crew training, operations control activities, flight crew operations support, aircraft maintenance and operations and life sciences operations support. The primary contractor is USA. The planning activities range from the development of operational concepts and techniques to the creation of detailed systems operational procedures and checklists. Tasks include:

(1) Flight planning;
(2) Preparing systems and software handbooks;
(3) Defining flight rules;
(4) Creating detailed crew activity plans and procedures;
(5) Updating network system requirements for each flight;
(6) Contributing to planning for the selection and operation of Space Shuttle payloads; and

(7) Preparation and plans for International Space Station assembly.

Also included are the Mission Control Center (MCC), Integrated Training Facility (ITF), Integrated Planning System (IPS) and the Software Production Facility (SPF). Except for the SPF (Space Shuttle only), these facilities integrate the mission operations requirements for both the Space Shuttle and International Space Station. Flight planning encompasses flight design, flight analysis and software activities. Both conceptual and operational flight profiles are designed for each flight and the designers also help to develop crew training simulations and flight techniques. In addition, the flight designers must develop unique, flight-dependent data for each mission. The data are stored in erasable memories located in the Orbiter, ITF Space Shuttle mission simulators and MCC computer systems. Mission operations funding also provides for the maintenance and operation of critical mission support facilities including the MCC, ITF, IPS and SPF. Finally, Mission and Crew Operations include maintenance and operations of aircraft needed for flight training and crew proficiency requirements.

Funds for other activities include implementing required modifications and upgrades on the T-38 aircraft used for space flight readiness training, capability improvements for weather prediction and enhancements on information handling to improve system monitoring, notably for anomaly tracking.

The major operations facilities at Johnson Space Center (JSC) include the Mission Control Center (MCC), the flight and ground support training facilities, the flight design systems and the training aircraft fleet that includes the Space Shuttle Training aircraft and the T-38 aircraft.

The Flight Operations budget also includes FY 2001 reimbursements that are assumed to be $4.4 million. These standard service reimbursements offset the total budget for the Space Shuttle and have been assumed in the NASA direct funding requirements identified above for the FY 2001 budget request.

SCHEDULES AND OUTPUTS

Space Shuttle Missions and Primary Payloads

FY 2001		Plan	Revised
STS-102/Discovery	Space Station #7 (MPLM-IP-01) (ISS-07-5A.1)	2nd Qtr FY 2000	October 2000
STS-100/Endeavour	Space Station #8 (MPLM-2P-01) (ISS-08-6A)	3rd Qtr FY 2000	November 2000
STS-107/Columbia	Microgravity Research Module/Spacehab	January 2001	
STS-104/Atlantis	Space Station #9 – Airlock (ISS-09-7A)	4th Qtr FY 2000	February 2001
STS-105/Atlantis	Space Station #10 (MPLM-IP-02) (ISS-10-7A.1)	4th Qtr FY 2000	March 2001
STS-106/Endeavour	Space Station #11 – MPLM-2P-02 (ISS-11-UF1)	April 2001	
STS-108/Columbia	Hubble Space Telescope (HST) Servicing Mission 3B	4th Qtr FY 2000	May 2001
STS-109/Atlantis	Space Station #12 (ITS-12-8A)	June 2001	
STS-110/Endeavour	Space Station #13 (ISS-13-UF2)	August 2001	

Operations Metrics	FY 1999 Plan	FY 1999 Actual	FY 2000 Plan	FY 2000 Revised	FY 2001 Plan
Number of Space Shuttle Flights	[6]	[4]	[8]	[6]	9
Shuttle Operations Workforce (Prime Contractor (equivalent personnel))	--	[13,800]	--	[13,353]	13,045
Number of Days On-orbit	[59]	[36]	[80]	[61]	202
Number of Primary Payloads Flown	[6]	[4]	[8]	[7]	11

ACCOMPLISHMENTS AND PLANS

In FY 2001, nine flights are planned to be flown, including seven ISS assembly and servicing missions, a dedicated microgravity research flight and another Hubble Space Telescope Servicing Mission (3B) will be flown.
The Shuttle program has provided launch support for space science missions accommodating universities and industry as a space laboratory and technology research vehicle. The Shuttle is also the only U.S. vehicle that provides human transportation to and from orbit. In FY 2001, 60 crewmembers are planned to fly approximately 1,280 days on-orbit, including time spent by Americans aboard the International Space Station.

BASIS OF FY 2001 FUNDING REQUIREMENT

PROGRAM INTEGRATION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Shuttle Integration	[145,300]	[178,300]	201,500
Shuttle Integration Upgrades	[6,700]	[900]	4,000
Program Management Support	[128,500]	[149,800]	113,300
Facilities Construction	[13,500]	[11,000]	15,600
(Safety allocation including upgrades - non-add)	(--)	(--)	(4,000)
Total	[294,000]	[340,000]	334,400

PROGRAM GOALS

The goal of Program Integration is to ensure the integration of the various Shuttle elements occurs successfully. Program Integration performs hundreds of modifications throughout the year related to design changes to improve reliability, supportability, or meet new program requirements. These changes are a result of hardware failures or design enhancements identified through ground checkouts or in-flight.

STRATEGY FOR ACHIEVING GOALS

The Program Integration budget was previously budgeted predominately in the Space Shuttle Operations budget under Orbiter and Integration along with the Construction of Facilities line in the Safety and Performance Upgrades budget, also some small residual funding came from other areas.

The Program Integration portion of the Space Operations budget includes funds for. analysis, management, and the SRM&QA function and are performed here for the entire Space Shuttle Program. In addition, this area includes funds for the infrastructure, taxes and directly funded construction of facilities projects.

Construction of Facilities (CofF) funding for Space Shuttle projects is provided in this budget to refurbish, modify, reclaim, replace and restore facilities at Office of Space Flight Centers to improve performance, address environmental concerns of the older facilities and to ensure their readiness to support Shuttle Operations.

SCHEDULES AND OUTPUTS

Complete Pad A Surface and Slope Restoration at LC-39 Plan: 1st Qtr. FY 01	This project provides for repair of the Pad A surface concrete, pad slopes, and the crawlerway grid path. Follow on project required, scope too extensive for budget and time allotted.
Rehabilitation of 480V Electrical Distribution System at MAF	External Tank manufacturing building Rehabilitation of the 480V Electrical Distribution System is a 4 phase project. Each phase will be implemented in the main manufacturing areas of building 103. Project Phasing and scope for each phase:
Complete Phase III Plan: 1st Qtr. FY 2001	Phase III, Substations Nos. 17A/17B will replace the core system, Transformers and switch gear, breakers and oil switches. Include some down stream cable, cable tray, and panel upgrades.
Complete Phase IV Plan: 2nd Qtr. FY 2001	Phase IV, Substations Nos., 7B, 4 & 5 – core system, transformers and switchgear, breakers and oil switches.
Complete Restoration of Pad A PCR Wall and Ceiling Integrity at Launch Complex (LC)-39 Plan: 1st Qtr. FY 01	This project provides for repair and replacement of damaged Payload Change Out Room (PCR) wall panels (Sides 1, 2, 3, & 4), replacement or elimination of deteriorated and leaking access doors, and other needed replacement and restoration. The modification will eliminate degrading flexducts and filter housings, improve pressurization of the PCR, provide an even distribution of airflow, and provide safe personnel access for maintenance and repair.

ACCOMPLISHMENTS AND PLANS

FY 2001 CoF funding will provide for improvements for facilities at JSC, KSC, MAF and SSC. At KSC there are 3 projects which complete the refurbishment of Pad B Payload Change Room (Wall and Ceiling), phase 1 of restoring low volt power system (Pad A and B), and the rehabilitation of high pressure distribution piping system (LC-39A/B). The JSC project repairs the roofs at Palmdale, Building 150. The SSC project modifies the A-2 Test Stand for Shuttle Testing. The MAF project repairs and upgrades the main electrical distribution system servicing the Vertical Assembly Building (110) and the Mix Room Building (130). For additional details on these projects, please refer to the Mission Support - Construction of Facilities budget.

To supplement the network of management reviews and government oversight functions, NASA continues to seek specific objective measurements of overall performance of the Shuttle Operations program. In order to permit rapid review by the program managers, the Shuttle program has devised a series of "stoplight" metrics. The metrics are devised whereby certain program aspects are measured against established limits or program parameters and then translated into the appropriate green, yellow or red indicators. Among the metrics displayed in this manner are in-flight anomalies, monthly cost rate, Shuttle processing monthly mishaps, Orbiter systems and line replaceable unit (LRU) problem reports, Shuttle processing contract overtime percentage and KSC quality surveillance error rate. The Shuttle program also tracks its launch history, monitoring the number of liftoff attempts per mission and characterizing any delays or scrubs as to technical, weather or operational-related reasons.

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **PAYLOAD UTILIZATION AND OPERATIONS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Payload carriers and support	39,200	49,300	[57,000]	HSF 3-3
Expendable launch vehicle mission support	31,500	30,600	[33,200]	HSF 3-5
Advanced projects	15,000	--	--	HSF 3-8
Engineering and technical base	96,300	85,200	[81,500]	HSF 3-10
OSF Contributions to Academic Programs (in ETB)	(2,300)	(2,300)	(8,000)	
Total	182,000	165,100	[171,700]	
Distribution of Program Amount by Installation				
Johnson Space Center	44,261	20,731	[29,400]	
Kennedy Space Center	66,765	79,068	[90,000]	
Marshall Space Flight Center	51,039	43,600	[37,100]	
Stennis Space Center	1,650	1,600	[200]	
Ames Research Center	300	--	[--]	
Glenn Research Center	450	--	[--]	
Langley Research Center	1,885	--	[--]	
Goddard Space Flight Center	15,000	8,900	[10,200]	
Jet Propulsion Laboratory	500	35	[--]	
Headquarters	150	11,166	[4,800]	
Total	182,000	165,100	[171,700]	

Note -- Beginning in FY 2001, the Payload Utilization and Operations Budget Line Item (BLI) has been divided into two new budget line items - Payload and ELV Support and Investments and Support. Payload carriers and support and ELV Mission Support move to the Payload and ELV support BLI, while Engineering and Technical Base moves to the Investments and Support BLI.

PROGRAM GOALS

There are several goals in the Payload Utilization and Operations budget. They range from supporting the processing and flight of Space Shuttle payloads and NASA payloads launched from Expendable Launch Vehicles (ELV), to ensuring maximum return on the research investment, to reducing operations costs, to continuing to implement flight and ground systems improvements, and to supporting strategic investments in advanced technology needed to meet future requirements.

STRATEGY FOR ACHIEVING GOALS

The principal areas of activity in the Payload Utilization and Operations program are: 1) provide safe and efficient payload preparations and launch and landing services while reducing costs of Space Shuttle-related services; 2) provide mission planning, integration and processing for science application missions utilizing –the Multiple-Purpose Experiment Support Structures (MPESS) and payload pallets; 3) within Advanced Projects, identify and develop advanced technology to support Shuttle, International Space Station (ISS) and future Human Exploration and Development of Space programs to improve safety and reduce costs, promote space commercialization and technology transfer, and manage the agency's Orbital Debris program; and 4) within Engineering and Technical Base (ETB), empower a core workforce to operate Human Space Flight laboratories, technical facilities, and test beds, and stimulate science and technical competence in the United States. The Payload Utilization and Operations budget reflects a commitment to meet a wide array of programs. This includes Space Shuttle and science missions, flight hardware development and integration, space flight safety projects, and maintenance of an institutional base from which to perform NASA programs at reduced cost through re-engineering, consolidation and operational efficiency processes. Beginning in FY 1999, Expendable Launch Vehicle (ELV) mission support was consolidated and transferred from Earth Science and Space Science to provide more focused and efficient management of launch services to be located at the Kennedy Space Center and Cape Canaveral Air Force Base in Florida.

Beginning in FY 2001, the Payload Utilization and Operations Budget Line Item (BLI) has been divided into two new budget line items - Payload and ELV Support and Investments and Support. Payload carriers and support and ELV Mission Support move to the Payload and ELV support BLI, while Engineering and Technical Base moves to the Investments and Support BLI.

BASIS OF FY 2001 FUNDING REQUIREMENT

PAYLAOD CARRIERS AND SUPPORT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Payload Carriers and Support	39,200	49,300	[57,000]

PROGRAM GOALS

The primary goal for Payload Carriers and Support is to safely and efficiently assemble, test, checkout, service, and integrate a wide variety of spacecraft and space experiments launched on the Space Shuttle.

STRATEGY FOR ACHIEVING GOALS

The Payload Carriers and Support program provides the technical expertise, facilities and capabilities necessary to perform payload buildup; test and checkout; integration and servicing of multiple payloads; transportation to the launch vehicle; and integration and installation into the launch vehicle. Included in this program are operational efficiencies gained to date, as well as additional anticipated efficiencies to reduce cost and improve customer satisfaction. Efficiencies already in place have reduced processing time. and error rate.

Payload Carriers and Support also funds small secondary payloads like the Get-Away Specials (GAS) and Hitchhiker payloads. The GAS payloads are research experiments that are flown in standard canisters, which can fit either on the sidewall of the cargo bay or across the bay on the GAS bridge. They are the simplest of the small payloads with limited electrical and mechanical interfaces. Approximately 155 GAS payloads have been flown. The Hitchhiker payloads are the more complex of the smaller payloads, and provide opportunities for larger, more sophisticated experiments. The Hitchhiker system employs two carrier configurations: (1) a configuration on the orbiter payload bay sidewall and (2) a configuration across the payload bay using a multi-purpose experiment support structure (MPESS). During the mission, the Hitchhiker payloads can be controlled and data can be received using the aft flight deck computer/standard switch panels or from the ground through the payload operations control center (POCC).

Payload analytical integration is the responsibility of the Payload Projects Office at the Marshall Space Flight Center (MSFC), and supported by a contract with Boeing. Physical payload integration and processing is the responsibility of the Payload Management and Operations Office at the KSC, and also supported by a contract with Boeing.

Another item funded in Paylaod Carriers and Support is the Flight Support System (FSS). The FSS consists of three standard cradles with berthing and pointing systems along with avionics. It is used for on-orbit maintenance, repair, and retrieval of spacecraft. The FSS is used on the Hubble Space Telescope (HST) repair/revisit missions.

SCHEDULES AND OUTPUTS

Missions Supported	FY 1999 Plan	FY 1999 Actual	FY 2000 Plan	FY 2000 Revised	FY 2001 Plan
Space Shuttle Missions	6	4	8	6	[9]
Hitchhiker Experiments, includes CAP/SEM/HH Jr.	13	12	4-6	2	[7]
Get-Away Special Payloads	5	5	10-20	0	[2]
Spacehab Missions	2	2	0	1	[1]
Other Major Payloads	8	6	8	6	[13]
Other Secondary Payloads	34	26	0	7	[1]
Multi-Purpose Experiment Support Structure (MPESS) Pallets	2	0	8	3	[5]
Number of Payload Facilities Operating at KSC	6	6	6	5	[5]
KSC Payload Ground Operations (PGOC) Workforce	360	366	334	308	[334]

ACCOMPLISHMENTS AND PLANS

In FY 1999, the Payload Carriers and Support provided the payload carrier and integration activities for the HST Orbital Systems Test (HOST) mission. Launch and landing payload support activities encompassed four Space Shuttle missions, including the first American segment of the ISS, and Payload Carriers and Support activities and facilities for six manifested major payloads. Twenty-six secondary payloads were also supported. The program also began preparation and initial analyses for HST Servicing Mission 3A, scheduled for launch in December 1999, with no additional funding. Operational efficiencies have reduced cost and improved customer satisfaction as well as reduced processing time and error rate. However, recent budget reductions will require closure of ground processing facilities, which will erode much of the progress made in recent years. Reimbursable funds of $806,000 were received in FY 1999 to cover processing costs for GAS and Hitchhiker payloads.

In FY 2000, Payload Carriers and Support will provide pallets for Hubble Space Telescope (HST) Servicing Mission 3A and for three of the ISS assembly flights. Launch and landing payload support activities will be provided for six Space Shuttle missions, encompassing Payload Carriers and Support activities and facilities for nine major payloads, including four ISS assembly and utilization flights. A number of secondary payloads will also be supported. Funding will also include the planning and processing of horizontally installed payloads in support of the Space Shuttle and ELV manifests; and providing operations and maintenance of five Payload Facilities at KSC. In order to fund the requirements of payload processing for the HST Servicing Mission added in FY 2000, NASA has placed the Vertical Processing Facility (VPF) at the Kennedy Space Center in a stand-by mode. While there are no current requirements in the Shuttle manifest for the unique capabilities of the VPF -- the VPF is the only vertical integration facility for Shuttle as well as the only hazardous Cargo Integration Test Equipment (CITE) location -- this could have potential impact on processing some payloads due to conflicts in remaining facilities. Funding includes a Construction of Facility Project in the amount of $750,000 for modifications/upgrades to the Spacecraft Assembly and Encapsulation Facility (SAEF)-2. Reimbursable funds of $1,125,000 is expected to be received in FY 2000 to cover processing costs for GAS and Hitchhiker payloads

Beginning in FY 2001, the Payload Carriers and Support budget will be in a new budget line item called Payload and ELV Support. Details on FY 2001 activity can be found in this section.

BASIS OF FY 2001 FUNDING REQUIREMENT

EXPENDABLE LAUNCH VEHICLE SUPPORT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Expendable Launch Vehicle Support	31,500	30,600	[33,200]

PROGRAM GOALS

The goals of the Expendable Launch Vehicle (ELV) mission support program are: (1) enhance probability of mission success and on-time cost effective launch services for NASA missions undertaken in support of NASA's strategic plan; (2) provide comprehensive advanced mission analysis and feasibility assessments for NASA payload customers; (3) increase efficiency in launch site operations and countdown management; and (4) provide low-cost secondary payload opportunities.

STRATEGY FOR ACHIEVING GOALS

NASA has consolidated ELV management and acquisition of launch services at Kennedy Space Center (KSC). Effective in FY 1999, all funding for mission support was transitioned from the Office of Space Science and the Office of Earth Science to the Office of Space Flight, consistent with assignment of responsibility for ELV management to OSF.

KSC is responsible for acquiring requisite launch services to meet all Enterprise requirements and for increasing the probability of mission success through focused technical oversight of commercially provided launch services. A core team of civil servants and contractors primarily located at KSC performs the technical management. KSC personnel are also resident at key launch sites, launch facilities and customer facilities. NASA personnel are resident at Vandenberg AFB in California where all launches into a polar orbit, such as those required by the Earth Science Enterprise, are conducted. Resident office personnel are located in launch service contractor plants, specifically, the Lockheed Martin Corporation Atlas Centaur plant in Denver and the Boeing Corporation Delta plant in Huntington Beach, California. KSC customer offices have been established at GSFC and JPL as the centers assigned program management responsibility for the majority of Space Science and Earth Science missions requiring access to space via NASA-provided launch services.

Advanced mission design/analysis and leading edge integration services are provided for the full range of NASA missions under consideration for launch on ELV's. Technical launch vehicle support is provided in the development and evaluation of spacecraft Announcement of Opportunities, to enable cost effective consideration of launch service options and technical compatibility. Early definition of vehicle requirements enables smooth transition to launch service and an excellent cost containment strategy.

Launch site operations and countdown management is being improved through the use of a consolidated launch team, efficient telemetry systems, and close partnership with Boeing and the USAF to assure lowest cost west coast Delta launch complex operations.

NASA's ELV secondary payload program enables efficient use of excess vehicle performance on selected NASA, USAF and commercial

missions through funding integration of small secondary payloads. These payloads are sponsored by university research institutions and often international cooperatives which can take advantage of available limited excess space and performance on launch vehicles and accept the primary payload's launch schedule and orbit. NASA has developed a standard Delta secondary launch vehicle capability and has similar discussions under way with other US ELV providers.

SCHEDULES AND OUTPUTS

	FY 1999		FY 2000		FY 2001
Missions Supported	Plan	Actual	Plan	Revised	Plan
ELV Missions	13	10	8	9	[11]
Secondary Payloads	3	1	3	5	[1]

ACCOMPLISHMENTS AND PLANS

During FY 1999, 13 ELV launches and 3 secondary ELV mission were planned. Ten were successfully launched (SWAS, Deepspace, Mars Orbiter, Mars Lander, Stardust, Landsat 7, FUSE, WIRE, Terriers, QuikScat) and three were delayed by contractor failure investigation activities until FY 2000 (TDRS-H, TERRA, and GOES-L). One secondary payload was launched (ORSTED/SUNSAT) and two secondaries (Munin/CE) were delayed due to the readiness of the primary spacecraft. Two contracts for launch services were signed under the Small ELV II acquisition effective December 1998. The ELV program negotiated launch of OES Vegetation Canopy Lidar payload using the Athena Launch Service residual from the cancelled Lewis mission and also supported NASA Wing Glove experiment launch and test on a commercial Pegasus mission. The modification/rehabilitation project of the Engineering and Operations Building located on Cape Canaveral Air Station, Florida, was started. Procurement and installation of a backup power supply system located at Vandenberg Launch Site Complex 2 (SLC-2) at Vandenberg Air Force Base (VAFB), California, was completed.

Support for 9 missions (Terra, GOES-L, HETE II, IMAGE, TDRS-H, EO-1, NOAA-L, HESS I, and VCL) and 5 secondaries (ACRIM, QUICKTOMS, MUNIN, Citizen Explorer, and ProSEDS) are planned for launch in FY 2000. Integration and technical management of 28 payloads, planned for launch in FY 2000 and FY 2001, are supported in this request along with mission analysis and studies in support of Flight Planning Board activities. The Gravity Probe-B mission moved from FY 2000 to FY 2001 due to spacecraft readiness. The JASON/TIMED mission also moved from FY 2000 to FY 2001.

Two launch services competitions are supported in this request. In FY 2000, the NASA Launch Services (NLS) procurement for purchasing launch services for future NASA missions – including potential Space Station re-supply missions– will be competed. This contract provides for awards to multiple contractors with vehicles with demonstrated flight history. Also, the Next Generation Launch Services (NGLS) contracts will be competed. NGLS will enable emerging launch services companies, with little or no flight history, to compete for offering launch services to NASA. The NLS NGLS procurements, in addition to the existing Small ELV (SELV) contracts will be used for the Alternative Access element of the Space Launch Initiative, for which funding begins in FY 2001 in the SAT account. Alternative Access funding is intended to enable NASA to establish and use alternative means of access to space – primarily to the International Space Station. These funds will be used to purchase services, however, in the near-term they may support technology development or operational technology demonstrations to help enable near term commercial launch systems that could service space station or launch NASA science payloads. Alternative access could provide important benefits, including contingency capability, operational flexibility, increased competition, near-term flight opportunities, and development of capabilities

to meet station-unique needs. The OSF ELV Program will work closely with OAST on Alternative Access and NASA envisions that funding for Alternative Access may be transferred from the SAT account to the HSF account in the future. This budget also supports two minor revitalization and Construction of Facilities at various locations.

Beginning in FY 2001, the ELV Mission Support budget will be in a new budget line item called Payload and ELV Support. Details on FY 2001 activity can be found in this section.

BASIS OF FY 2001 FUNDING REQUIREMENT

ADVANCED PROJECTS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Advanced projects	15,000	--	--

PROGRAM GOALS

In FY 1999, NASA reallocated all of the Advanced Projects funding to meet critical needs for the International Space Station (ISS) with the exception of the X-38 project. The X-38 project was merged into the Crew Return Vehicle (CRV) Program starting in FY 2000.

STRATEGY FOR ACHIEVING GOALS

The X-38 experimental vehicle program is specifically intended to demonstrate the technologies and processes required reducing the risks of developing a CRV in a "better, faster, cheaper" mode. Evaluations of the performance of the technologies of the X-38 systems are conducted through a series of ground, air, and space tests. The X-38 is based on the U.S. Air Force/Martin-Marietta X-24A lifting body research vehicle. Successful demonstration of the X-38 technologies is a precursor to the decision process to develop a long-term crew return capability for the International Space Station. Through cooperative arrangements that are under discussion with the European Space Agency, the DOD, and the Japanese Space Agency, NASA also seeks to identify opportunities for the commonality among space vehicles being developed. An independent study was initiated in FY 1998 to assess the cost estimates and applicability of the X-38 design for the Space Station CRV. Continuing studies will assess options for a Crew Transfer Vehicle (CTV) and other options which meet the Space Station's crew rescue requirements and will augment the industry-led Future Launch studies described in the Aeronautics and Space Transportation Technology section. The decision on whether to proceed with an X-38 based CRV design will be made in two years, in the context of broader decisions that NASA and the Administration will make regarding future space transportation architectures. Funding for Phase 2 of CRV development resides in the SAT account, pending these decisions.

SCHEDULES AND OUTPUTS

CRV Formulation Study Plan: 3rd Qtr FY 1998 Actual: 1st Qtr FY 1999	Initiate independent assessment regarding the cost and applicability of the X-38 design for the CRV.
Flight test for the third atmospheric vehicle Plan: 4th Qtr FY 1999 Actual: Under review	Additional testing will be conducted to demonstrate full lifting body control, using the sub-scale vehicle with final shape.

Shuttle Space Flight Test for Vehicle 201 — Currently manifested for February 2002

Plan: 2nd Qtr FY 2002

ACCOMPLISHMENTS AND PLANS

The X-38 experimental vehicle program is specifically intended to demonstrate the technologies and processes required to produce a human-rated spacecraft such as a Crew Return Vehicle (CRV) in a "better, faster, cheaper mode." A crew return capability is necessary for permanent human habitation of the International Space Station to ensure crew safety. The Russian Soyuz spacecraft will provide crew return vehicle capability during the 3-crew member stage, and could provide an interim capability during the 6-crew member stage, until an U.S. system becomes operational in 2005. Evaluations of the performance of the technologies of the X-38 systems are conducted through a series of ground, air, and space flight tests. The first atmospheric flight test was conducted on March 12, 1998. The X-38 test vehicle (Vehicle 131; 24 ft. scale vs. 30 ft scale for operational CRVs) was dropped under the wing of a NASA B-52. It successfully deployed its parafoil parachute and completed a guided descent from 23,000 feet altitude to a nominal landing. Additional atmospheric flight tests are scheduled to continue using three increasingly complex test vehicles. The second flight for Vehicle 131 was successfully completed on February 6, 1999. In FY 1999, Vehicle 132 also underwent flight testing at the Dryden Flight Research Center. Vehicle 132 completed two lifting body flight control system flight tests using Electro Mechanical Actuators (EMAs) for aero-surface control. The X-38 space flight test vehicle (Vehicle 201) is full 30-ft. operational scale and is scheduled for launch on the Space Shuttle in early 2002 (currently manifested for February 2002) to demonstrate the full range of CRV flight operations, including space flight, reentry and parafoil landing test. The primary structure for Vehicle 201 (Space Test Vehicle) was completed in FY 1999, the initial wiring was installed, and the cabin pressure testing was successfully completed. The X-38 program completed a 9-month Independent Assessment (IA) in which 110 maturity gate action items were identified to ensure costs savings are realized -- 57 of these actions were completed in FY 1999, including construction of a full scale (7500 sq. ft) parafoil. FY 1999 accomplishments also include completed modifications to X-38 Vehicle 131 (to 131R) into an operational aerodynamic configuration for future flight testing; improvements to parafoil deployment dynamics; first use of neural net based flush air data system; flight readiness of dynamic inversion (MACH) flight control system (V132); completion of Deorbit Propulsion Stage CDR; and completion of electromagnetic docking/berthing testbed.

Since the scope of the X-38 project objectives were significantly expanded to include early development of technologies directly usable on an operational CRV, the X-38 project will be merged into the CRV project as a part of the ISS Program. X-38 milestones and program costs, including completion of CRV operational technology developments and the Vehicle 201 space flight test will be tracked as an element of the CRV project budget within Space Station.

BASIS OF FY 2001 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Engineering and technical base	96,300	85,200	--

PROGRAM GOALS

The focus of the Engineering and Technical Base (ETB) is to support the institutional capability in the operation of space flight laboratories, technical facilities, and testbeds; to conduct independent safety, and reliability assessments; and to stimulate science and technical competence in the United States. ETB activities are carried out at the Johnson Space Center (JSC) including White Sands Test Facility (WSTF), Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), and Stennis Space Center (SSC). ETB funds are used to: maintain the Centers' technical competence and ability to perform research; analysis and testing tasks; to solve present problems; and to reduce costs in developing programs, technologies, and materials. Efforts include system and mission analysis, integrated HSF Research and Technology (R&T) requirements definition and integration, modest R&T investments in an EVA technology demonstration project and investments in R&T required supporting the integrated Office of Space Science/HEDS robotic efforts.

STRATEGY FOR ACHIEVING GOALS

The complex and technically challenging programs managed by the Office of Space Flight (OSF), now and in the future, are most effectively carried out by sustaining a NASA "core" institutional technical base. It is vital to preserve essential competency and excellence. Since FY 1994, the OSF centers have consolidated activities and have identified ways to economize the resources committed to ETB while maintaining ETB's benefits to the nation's human space flight program. Over the next few years, this consolidation will continue to generate savings through improved information resources management and contract streamlining. A prioritized core capability will include multi-program labs and test facilities, associated systems, equipment, and a full range of skills capable of meeting research, testing and simulation demands.

As the ETB budget is reduced, several activities will continue to refine current business practices. Mandatory equipment repair and replacement will be reassessed. Software applications for multi-program analytical tools will be implemented. The strategy to better manage the NASA investment in information processing resources includes aggressive actions to integrate and consolidate more ADP operations. ETB will ensure synergism among major NASA engineering programs. Awards for education and research tasks will be granted to support educational excellence and research learning opportunities in colleges and universities. A key challenge of the ETB strategy will be to provide a core capability for future human space flight endeavors with fewer resources. Adoption of new innovative processes to meet critical ETB core requirements and streamlining or eliminating non-critical capabilities will enable future savings.

In the President's FY 2001 budget request, funding for Engineering and Technical Base is moved from the Payload Utilization and Operations budget line item to a new budget line item, Investments and Support.

SCHEDULES AND OUTPUTS

Laboratories & facilities supported (KSC)	Maintains 11 science and engineering laboratories in support of 6 agency programs
Laboratories & facilities supported (JSC)	Maintains 156 science and engineering laboratories in support of 52 agency programs
Laboratories & facilities supported (MSFC)	Maintains 123 science and engineering laboratories and facilities in support of 42 agency programs
Laboratories & facilities supported (SSC)	Maintains 3 science and engineering laboratories in support of 2 agency programs
NASA Minority University Research and Education Program at JSC, KSC, MSFC & SSC	Award education and research grants

ACCOMPLISHMENTS AND PLANS

In FY 1999, KSC implemented the Outsourcing and Desktop Initiative NASA (ODIN) contract to consolidate basic information technology (i.e., desktop maintenance, network administration, intra-network connections) for JSC, KSC, MSFC, and SSC. These Centers transitioned applicable ETB-funded IT support to ODIN as part of this consolidation effort.

In FY 1999, JSC received workstation support through the Outsourcing Desktop Initiative for NASA (ODIN). JSC's Information Systems Directorate will work with the selected vendor to ensure adequate scientific, technical, and engineering computing capability is received at the lowest possible cost. In FY 2000, ETB will continue to provide vital support to JSC science and engineering lab infrastructure. FY 2000 contains many critical programmatic milestones that will require extensive support from our labs. NASA needs to perform many critical studies, tests, and analyses for many activities. These include: monitoring human life support and crew health as we begin to inhabit Station in FY 2000; and ensuring the Shuttle can safely operate and transport Station hardware and astronaut personnel; ensuring smooth and safe operations of personnel and equipment during the Station assembly EVAs. In addition, ETB will keep our labs operational to perform exploration and development studies.

The Engineering and Technical Base also supports Information Resource Management (IRM). IRM processing achieved efficiencies and improved economies of scale through the consolidation of IBM-compatible mainframes supporting administrative and programmatic automated data processing (ADP) services at the NASA ADP Consolidation Center (NACC) located at MSFC. The NACC continues to seek new and innovative ways to achieve cost savings.

The NACC provides supercomputing capability for its customers for engineering and scientific computer-intensive applications seven days a week. The NACC supercomputing facility was established in FY 1994 and is managed through the MSFC NACC Project Office. The NACC supercomputing facility includes a mainframe located at MSFC and a smaller distributed system located at JSC, supporting customers at both Centers. The NACC supercomputer facilities include hardware and software to conduct thermal radiation analyses, computational fluid dynamics, structural dynamics and stress analyses for NASA programs such as the Space Shuttle, X-33, X-34, Space Station, and Reusable Launch Vehicle. The facilities also conduct certification and engineering performance evaluation of flight and test data.

In cooperation with the goals of the NASA Minority University Research and Education Program, ETB enables the Space Flight Centers to participate in programs to stimulate science and technical competence in the nation. The ETB program enabled the Centers to award education and research grants to Historically Black Colleges and Universities (HBCU). Examples include: solution crystal growth in low gravity; organic fiber optic sensors; hydrology, soil climatology, and remote sensing; and cytogenic investigations into radiosensitivity, genetic instability and neoplasti. JSC will be awarding approximately $1.0 million in new research grants to Historically Black Colleges and Universities and Other Minority Universities. MSFC, KSC and SSC also participate in programs to stimulate science and technical competence by participating in education and research grants with Historically Black Colleges and Universities (HBCU) and Other Minority Universities (OMUs).

In FY 1999, KSC continued to achieve ZBR-recommended reductions in FY 1999 by reengineering CAD/CAE services including migration to PC platform and elimination of VAX mainframe/software and associated maintenance. MSFC and SSC will continue institutional support while continuing to strive for institutional efficiencies. In FY 1999 and FY 2000, KSC will continue to achieve cost efficiencies in the operation of existing core laboratories and associated technical ADP services which will enable necessary equipment/system upgrades and implementation of strategic core technical development initiatives that support our Center of Excellence assignment.

In FY 2000 the ETB budget will continue to implement the Agency's Zero-Base Review (ZBR) recommendations. These include a reduced level of science and engineering lab support to human space flight programs, streamlined technical operations, additional ADP consolidation activities, and reduced education and research awards funding. These reductions will require that all Centers continue to assess their range of workforce skills, analytical tools and facilities dedicated to ensure their ability to provide space flight institutional engineering support for future human space flight programs and the existing customer base. Center assessments will focus on maintaining core support for design, development, test and evaluations, independent assessments, simulation, operations support, anomaly resolution, and systems engineering activities.

In FY 2000, there will be an effort to include systems analysis and modest investments in research and technology to meet long-term HSF requirements included in the ETB budget. The In-House HEDS Studies for FY2000 will address systems definition and analysis, and technology road map definition for a wide variety of potential options for future HEDS programs to improve safety and reduce costs; to promote space commercialization and technology transfer; and to enable future missions. These studies will be closely integrated with agency next decade planning activities and the HEDS Technology/Commercialization initiative. ISS and Space Shuttle may be addressed as supporting infrastructure aspects of the in-house studies, if appropriate, but are not planned to be the principal focus of these efforts. Systems Analysis will provide for overall planning and analysis for development of new technology, focusing on innovative, high-leverage technologies and approaches which will enable the development of new capabilities to meet future human space flight needs, and providing the opportunity for enhanced synergy between ongoing programs and future HEDS objectives. Studies will include the following activities:

- Overall technical integration and development of technical requirements, technology roadmaps, and investment strategies;
- Evaluation of alternative mission approaches and technologies;
- Development of advanced transportation system architectures and technology requirements;
- Definition of R&T for Advanced Power, Information Systems Technology, and Advanced Sensors;
- System & concept definition and identification of proof-of-concept tests/ demonstrations for key emerging HEDS technologies/systems;
- ISS evolution systems analysis to determine far-term mission requirements and concepts for cost reduction and performance enhancement; and
- Identification of candidate HEDS payloads for future Mars robotics missions providing low cost environmental data and technology demonstrations that are necessary to enable safe exploration missions in the future.

Intelligent Synthesis Environment (ISE) testbeds will be initiated in FY 1999 to provide NASA engineers and scientists with the tools and infrastructure to facilitate the development of new technology, analysis and modeling tools for mission architectures. The centers' ISE requirements are further addressed in the agency's FY 2000 ISE initiative for which funding is requested in the Research and Technology Base of the Aeronautics program with an increased focus on commercial space development initiatives.

ETB will support implementation of HEDS experiments for the Office of Space Science Mars's missions, as appropriate.

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **PAYLOAD AND ELV SUPPORT**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Payload Carriers and Support	[39,200]	[49,300]	57,000	HSF 4-3
Expendable Launch Vehicle Mission Support	[31,500]	[30,600]	33,200	HSF 4-5
Total	[70,700]	[79,900]	90,200	
Distribution of Program Amount by Installation				
Johnson Space Center	[1,400]	[1,300]	1,300	
Kennedy Space Center	[53,675]	[66,565]	77,600	
Marshall Space Flight Center	[525]	[3,100]	1,100	
Langley Research Center	[500]	[--]	--	
Goddard Space Flight Center	[14,600]	[8,900]	10,200	
Jet Propulsion Laboratory	[--]	[35]	--	
Total	[70,700]	[79,900]	90,200	

Note: Both of these projects were previously funded in the Payload Utilization and Operations budget line item in FY 1999 and FY 2000. Beginning in FY 2001, these projects will be funded from this new budget line item.

PROGRAM GOALS

The Payload and ELV Support comprises two projects: Payload Carriers and Support and Expendable Launch Vehicle (ELV) Mission Support. Payload Carriers and Support provides technical expertise, facilities, flight carrier hardware and capabilities necessary to

perform payload buildup; test and checkout; integration and servicing of multiple payloads; transportation to the Space Shuttle; and integration and installation into the Space Shuttle.

Expendable Launch Vehicle (ELV) Mission Support has four goals. They are: (1) enhance probability of mission success and on-time cost effective launch services for NASA missions undertaken in support of NASA's strategic plan; (2) provide comprehensive advanced mission analysis and feasibility assessments for NASA payload customers; (3) increase efficiency in launch site operations and countdown management; and (4) provide low-cost secondary payload opportunities.

STRATEGY FOR ACHIEVING GOALS

The principal areas of activity in the Payload and ELV Support programs are: 1) provide safe and efficient payload preparations and launch and landing services while reducing costs of Space Shuttle-related services; and 2) provide mission planning, integration and processing for science application missions.

The Payload and ELV Support budget reflects a commitment to meet a wide array of programs ranging from science missions, flight hardware development and integration, and space flight safety projects. It also maintains an institutional base from which to perform NASA programs at reduced cost through re-engineering, consolidation and operational efficiency processes. Beginning in FY 1999, Expendable Launch Vehicle (ELV) mission support was consolidated and transferred from Earth Science and Space Science to provide more focused and efficient management of launch services to be located at the Kennedy Space Center and Cape Canaveral Air Force Base in Florida.

BASIS OF FY 2001 FUNDING REQUIREMENT

PAYLOAD CARRIERS AND SUPPORT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Payload Carriers and Support	[39,200]	[49,300]	57,000

PROGRAM GOALS

The primary goal for Payiaod Carriers and Support is to safely and efficiently assemble, test, checkout, service, and integrate a wide variety of Space Shuttle spacecraft and space experiments.

STRATEGY FOR ACHIEVING GOALS

The Payload Carriers and Support program provides the technical expertise, facilities and capabilities necessary to perform payload buildup; test and checkout; integration and servicing of multiple payloads; transportation to the launch vehicle; and integration and installation into the launch vehicle. This program also includes operational efficiencies gained to date, as well as additional anticipated efficiencies to reduce cost and improve customer satisfaction. Efficiencies already in place have reduced processing time and error rate.

Payload Carriers and Support also funds smaller secondary payloads like the Get-Away Specials (GAS) and Hitchhiker payloads. The GAS payloads are research experiments that are flown in standard canisters, which can fit either on the sidewall of the cargo bay or across the bay on the GAS bridge. They are the simplest of the small payloads with limited electrical and mechanical interfaces. Approximately 155 GAS payloads have been flown. The Hitchhiker payloads are the more complex of the smaller payloads, and provide opportunities for larger, more sophisticated experiments. The Hitchhiker system employs two carrier configurations: (1) a configuration on the orbiter payload bay sidewall and (2) a configuration across the payload bay using a multi-purpose experiment support structure (MPESS). During the mission, the Hitchhiker payloads can be controlled and data can be received using the aft flight deck computer/standard switch panels or from the ground through the payload operations control center (POCC).

Payload analytical integration is the responsibility of the Payload Projects Office at the Marshall Space Flight Center (MSFC), and supported by a contract with Boeing. Physical payload integration and processing is the responsibility of the Payload Management and Operations Office at the KSC, and also supported by a contract with Boeing.

Another item funded in Payload Carriers and Support is the Flight Support System (FSS). The FSS consists of three standard cradles with berthing and pointing systems along with avionics. It is used for on-orbit maintenance, repair, and retrieval of spacecraft. The FSS is used on the Hubble Space Telescope (HST) repair/revisit missions.

MEASURES OF PERFORMANCE

	FY 1999		FY 2000		FY 2001
Missions Supported	Plan	Actual	Plan	Revised	Plan
Space Shuttle Missions	[6]	[4]	[8]	[6]	9
Hitchhiker Experiments, includes CAP/SEM/HH Jr.	[13]	[12]	[4-6]	[2]	7
Get-Away Special Payloads	[5]	[5]	[10-20]	[0]	2
Spacehab Missions	[2]	[2]	[--]	[1]	1
Other Major Payloads	[8]	[6]	[8]	[6]	13
Other Secondary Payloads	[34]	[26]	[--]	[7]	1
Multi-Purpose Experiment Support Structure (MPESS)					--
Pallets	[2]	[0]	[8]	[3]	5
Number of Payload Facilities Operating at KSC	[6]	[6]	[6]	[5]	5
KSC Payload Ground Operations (PGOC) Workforce	[360]	[366]	[334]	[308]	334

ACCOMPLISHMENTS AND PLANS

In FY 2001, Payload Carriers and Support will provide pallets, integration and testing support activities for HST Servicing Mission 3B. Launch and landing payload support activities include 9 planned Space Shuttle Missions, encompassing payload processing support activities and facilities for 13 major payloads, including 6 ISS assembly and utilization flights. Funding also provides operations and maintenance of Payload Facilities at KSC. It is planned that reimbursable funds of $1,155,000 will be received in FY 2001 to cover processing costs for GAS and Hitchhiker payloads.

BASIS OF FY 2001 FUNDING REQUIREMENT

EXPENDABLE LAUNCH VEHICLE SUPPORT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Expendable Launch Vehicle Support	[31,500]	[30,600]	33,200

PROGRAM GOALS

The goals of the Expendable Launch Vehicle (ELV) mission support program are to: (1) enhance probability of mission success and on-time cost effective launch services for NASA missions undertaken in support of NASA's strategic plan; (2) provide comprehensive advanced mission analysis and feasibility assessments for NASA payload customers; (3) increase efficiency in launch site operations and countdown management; and (4) provide low-cost secondary payload opportunities.

STRATEGY FOR ACHIEVING GOALS

NASA has consolidated ELV management and acquisition of launch services at Kennedy Space Center (KSC). Effective in FY 1999, all funding for mission support was transitioned from the Office of Space Science and the Office of Earth Science to the Office of Space Flight, consistent with assignment of responsibility for ELV management to OSF.

KSC is responsible for acquiring requisite launch services to meet all Enterprise requirements and for increasing the probability of mission success through focused technical oversight of commercially provided launch services. A core team of civil servants and contractors primarily located at KSC performs the technical management. KSC personnel are also resident at key launch sites, launch facilities and customer facilities. NASA personnel are resident at Vandenberg AFB in California where all launches into a polar orbit, such as those required by the Earth Science Enterprise, are conducted. Resident office personnel are located in launch service contractor plants, specifically, the Lockheed Martin Corporation Atlas Centaur plant in Denver and the Boeing Corporation Delta plant in Huntington Beach, California. KSC customer offices have been established at GSFC and JPL as the centers assigned program management responsibility for the majority of Space Science and Earth Science missions requiring access to space via NASA-provided launch services.

Advanced mission design/analysis and leading edge integration services are provided for the full range of NASA missions under consideration for launch on ELV's. Technical launch vehicle support is provided in the development and evaluation of spacecraft Announcement of Opportunities, to enable cost effective consideration of launch service options and technical compatibility. Early definition of vehicle requirements enables smooth transition to launch service and an excellent cost containment strategy.

Launch site operations and countdown management is being improved through the use of a consolidated launch team, efficient telemetry systems, and close partnership with Boeing and the USAF to assure lowest cost west coast Delta launch complex operations.

NASA's ELV secondary payload program enables efficient use of excess vehicle performance on selected NASA, USAF and commercial missions through funding integration of small secondary payloads. These payloads are sponsored by university research institutions and often international cooperatives which can take advantage of available limited excess space and performance on launch vehicles and accept the primary payload's launch schedule and orbit. NASA has developed a standard Delta secondary launch vehicle capability and has similar discussions under way with other US ELV providers.

MEASURES OF PERFORMANCE

	FY 1999		FY 2000		FY 2001
Missions Supported	Plan	Actual	Plan	Revised	Plan
ELV Missions	[13]	[10]	[8]	[9]	11
Secondary Payloads	[3]	[1]	[3]	[5]	1

ACCOMPLISHMENTS AND PLANS

Two launch services competitions are supported in this request. In FY 2000, the NASA Launch Services (NLS) procurement for purchasing launch services for future NASA missions – including potential Space Station re-supply missions– will be competed. This contract provides for awards to multiple contractors with vehicles with demonstrated flight history. Also, the Next Generation Launch Services (NGLS) contracts will be competed. NGLS will enable emerging launch services companies, with little or no flight history, to compete for offering launch services to NASA. The NLS NGLS procurements, in addition to the existing Small ELV (SELV) contracts will be used for the Alternative Access element of the Space Launch Initiative, for which funding begins in FY 2001 in the SAT account. Alternative Access funding is intended to enable NASA to establish and use alternative means of access to space – primarily to the International Space Station. These funds will be used to purchase services, however, in the near-term they may support technology development or operational technology demonstrations to help enable near term commercial launch systems that could service space station or launch NASA science payloads. Alternative access could provide important benefits, including contingency capability, operational flexibility, increased competition, near-term flight opportunities, and development of capabilities to meet station-unique needs. The OSF ELV Program will work closely with OAST on Alternative Access and NASA envisions that funding for Alternative Access may be transferred from the SAT account to the HSF account in the future.

In FY 2001, the ELV Sustaining effort will support launch site maintenance and sustaining operations at Vandenberg AFB and Cape Canaveral Air Station. It will also support technical insight across all launch vehicle classes (Small, Med-Lite, Medium, & Intermediate), and support for 11 missions (including GENESIS, Mars Orbiter, TIMED/JASON, ICESAT/CATSAT, NOAA-M, GALEX) and 1 secondary payload (IMEX) to be launched in FY 2001. This also supports the assessment of necessary modification and/or replacement of the NASA Operations Center at Vandenberg Air Force Base, CA.

HUMAN SPACE FLIGHT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **INVESTMENTS AND SUPPORT**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Rocket Propulsion Test Support	[23,659]	[24,500]	28,000	HSF 5-3
OSF Contributions to Academic Programs	[3,128]	[3,100]	8,000	HSF 5-5
Advanced Projects	[15,000]	[--]	--	
Technology and Commercialization	[--]	[--]	20,000	HSF 5-7
Engineering and technical base	[90,672]	[79,300]	73,500	HSF 5-10
Total	[132,459]	[106,900]	129,500	
Distribution of Program Amount by Installation				
Johnson Space Center	[46,329]	[22,331]	30,800	
Kennedy Space Center	[13,460]	[12,903]	12,800	
Marshall Space Flight Center	[49,896]	[40,500]	37,800	
Stennis Space Center	[19,591]	[20,000]	23,300	
Ames Research Center	[300]	[--]	--	
Glenn Research Center	[450]	[--]	--	
Langley Research Center	[1,385]	[--]	--	
Goddard Space Flight Center	[400]	[--]	--	
Jet Propulsion Laboratory	[500]	[--]	--	
Headquarters	[150]	[11,166]	24,800	
Total	[132,459]	[106,900]	129,500	

Note - FY 1999 and FY 2000 data in this section are for comparison purposes only. See Payload Utilization and Operations sections for more details.

PROGRAM GOALS

There are several goals in the Investments and Support. They range from supporting rocket propulsion test support, supporting for NASA's academic programs, to ensuring maximum return on the research investment, to reducing operations costs, to continuing to implement flight and ground systems improvements, and to supporting strategic investments in advanced technology needed to meet future requirements and enabling synergistic commercial space development efforts.

STRATEGY FOR ACHIEVING GOALS

The Investments and Support budget reflects a commitment to meet a wide array of programs. The principal areas of activity in the Investments and Support program are: 1) provide leadership in the area of rocket propulsion testing, 2) provide additional support to NASA's academic programs, 3) within Technology and Commercialization to develop and promote space commercialization and technology transfer, and; 4) within Engineering and Technical Base (ETB), empower a core workforce to operate Human Space Flight laboratories, technical facilities, and test beds, and stimulate science and technical competence in the United States, and maintenance of an institutional base from which to perform NASA programs at reduced cost through re-engineering, consolidation and operational efficiency processes.

The Investments and Support budget is a new budget line item in the FY 2001 budget. Funding for this new budget line, with the exception of the Technology and Commercialization program, will be established from programs previously funded in the Human Space Flight and Mission Support Appropriations. Specifically, the Engineering and Technical Base was previously funded from the Payload Utilization and Operations budget line item in FY 1999 and FY 2000. The Enterprise Contribution to Academic Programs was previously funded from both Space Shuttle and Payload Utilization and Operations. The Rocket Propulsion Test Program was previously funded in the following BLIs: Space Shuttle, Engineering and Technical Base, Space Station and Research and Program Management (R&PM). The Technology and Commercialization project is a new start for FY 2001. Beginning in FY 2001, all of these projects will be funded from this new budget line item.

BASIS OF FY 2001 FUNDING REQUIREMENT

ROCKET PROPULSION TEST SUPPORT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Rocket Propulsion Test Support	[23,659]	[24,500]	28,000

PROGRAM GOALS

A new Budget Line Item (BLI) has been established beginning in FY 2001 to ensure NASA's rocket propulsion test capabilities are properly managed and maintained in world class condition. The Rocket Propulsion Test Support Program is not a new activity, but a consolidation of ongoing activities to achieve a more effective test program. The Rocket Propulsion test Program was previously funded in the following BLIs: Space Shuttle, Engineering and Technical Base, Space Station and Research and Program Management (R&PM). This consolidation will significantly enhance NASA's ability to properly manage our rocket testing activities and infrastructure.

STRATEGY FOR ACHIEVING GOALS

Stennis Space Center (SSC) has been appointed as Lead Center for Propulsion Testing to manage this initiative, which includes making test assignments and approval of test facility investments. Funding for this program provides:

1) sustaining support for propulsion test facilities which include test positions and related infrastructure at SSC, JSC-WSTF, GRC-PB and MSFC;
2) modernization/upgrades of existing facilities to ensure their capabilities are adequate to meet the demands of our future customers and to optimize their operating efficiency;
3) administrative/technical support to SSC for scheduling and management of propulsion testing across the agency and coordination of these activities with DoD and commercial customers; and
4) development of test technologies to improve analytical capabilities, hardware health monitoring, and operational safety and achieve cost savings through enhanced operational efficiencies.

NASA has established a Rocket Propulsion Test Management Board (RPTMB) under Stennis Space Center purview, which is NASA's Lead Center for Rocket Propulsion Testing. The RPTMB is composed of representatives from all four NASA rocket test centers (SSC, MSFC, JSC-White Sands and GRC-Plum Brook) and is chaired by SSC. The RPTMB has established baseline test roles for each center, resulting in the consolidation of test capabilities and the elimination of redundant facilities and related infrastructure. The roles are tailored to take advantage of existing unique capabilities at each site and to consolidate capabilities where it makes sense. The RPTMB makes test assignments, controls investments, and manages personnel and equipment sharing among NASA's test sites.

In addition, NASA has been key to the formation and development of the National Rocket Propulsion Test Alliance (NRPTA). NASA and DoD test sites are cooperating to share people and equipment, review/track investments, and make interagency test

assignments that will improve test support and avoid redundant investments in federally owned and operated test facilities. The NRPTA maintains an integrated national rocket test facility schedule and utilization rate, along with detailed data on NASA/DoD test facility capabilities.

SCHEDULE AND OUTPUTS

Improve NASA test capabilities through modernization and upgrades of various test facilities

Improve altitude system capability and efficiency Plan: 4th Qtr FY 2000	Improve altitude system capability and efficiency at JSC-WSTF and GRC-PB
High-pressure spares and equipment upgrades Plan: 3rd Qtr FY 2000	Provide critical high-pressure spares and equipment upgrades for E Complex at SSC

Improve NASA test capabilities and achieve cost savings by implementation of planned facility readiness/closure plans

Commercial Operations Plan: 2nd Qtr FY 2000	Complete integration of commercial operations on test stand B-1 at SSC
Activate cells 2 and 3 of E-1 at SSC Plan: 4th Qtr FY 2000	
Mothball test stand 4670 at MSFC Plan: 3rd Qtr FY 2000	Mothball test stand 4670 at Marshall Space Flight Center

Enhance test diagnostics capabilities and increase operational efficiencies through implementation of new test technologies.

H2 Leak Detection System Plan: 4th Qtr FY 2000	Develop improved H2 Leak Detection System for A/B test stand at Stennis Space Center
Development of plume diagnostics Plan: 4th Qtr FY 2000	Complete development of plume diagnostics research activities to detect metals in exhaust plumes
Modular test hardware Plan: 4th Qtr FY 2000	Initiate development of modular test hardware prototype

Advanced data acquisition and controls development laboratory Plan: 4th Qtr FY 2000	Complete advanced data acquisition and controls development laboratory

Improve coordination/management of propulsion testing between NASA and DoD via efforts by the Rocket Propulsion Test Management Board (RPTMB)

Scheduling/integration tools and processes Plan: 4th Qtr FY 2000	Develop improved scheduling/integration tools and processes
NASA/DoD cross-agency test assignments Plan: 4th Qtr FY 2000	Achieve six NASA/DoD cross-agency test assignments
Integration and assignment process in conjunction with DoD Plan: 4th Qtr FY 2000	Establish test integration and assignment process in conjunction with DoD
Increase the number of Air Force test personnel Plan: 4th Qtr FY 2000	Increase the number of Air Force test personnel at SSC from 1 to 3

Ongoing Measures of Performance:

1) Improve NASA test capabilities through modernization and upgrades of various test facilities
   a. Improve thrust measurement capability at selected test positions
   b. Upgrade Test Complex Control Room systems and equipment at various test positions
2) Improve NASA test capabilities and achieve cost savings by implementation of planned facility readiness/closure plans
   a. Demonstrate two-day turnaround on all major test projects
   b. Ensure less than 5% of tests are delayed by facility problems
3) Enhance test diagnostics capabilities and increase operational efficiencies through implementation of new test technologies
   a. Develop non-intrusive instrumentation and controls

ACCOMPLISHMENTS AND PLANS

Over the last two years, decisions made and actions taken by NASA's Rocket Propulsion Test Management Board (RPTMB) has resulted in an estimated total savings of approximately $37 million, while the National Rocket Propulsion Test Alliance (NRPTA) has contributed another $10 million. To date, the RPTMB has made 25 propulsion test assignments within NASA, across other

agencies, and to industry facilities where it was in the best interest of NASA. During FY 2001, the agency will implement critical facility upgrades to ensure existing test assets are truly the best in the world, providing flexible and robust testing capabilities operated by a highly experienced and trained cadre of test personnel. The RPTMB will continue to make test assignments that optimize utilization of existing test facilities across the agency and achieve further cost savings. Efforts will also continue in the upcoming fiscal year to execute planned facility closures and activate test facilities currently being modified in preparation for planned testing in FY 2001 and beyond. Investments in new test technologies such as exhaust plume diagnostics and H2 leak detection will enhance our ability to monitor the status of hardware during testing and increase operational safety. Investments will also be made in the development of improved scheduling tools, test technology, and modularization of test support hardware to reduce turnaround times, improve test management capabilities and improve overall operational efficiencies.

BASIS OF FY 2001 FUNDING REQUIREMENT

OSF CONTRIBUTION TO ACADEMIC PROGRAMS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
OSF Contribution to Academic Programs	[3,100]	[3,100]	8,000
Education Programs.	[--]	[--]	[2,500]
Minority University Research and Education Programs	[3,100]	[3,100]	[5,500]

PROGRAM GOALS

The goal of the Office of Space Flight (OSF) Contribution to Academic Programs is to provide additional funding to support NASA direction for academic programs as set forth in the NASA Strategic Plan as one of the Agency's five contribution to the Nation's science and technology goals and priorities.

STRATEGY FOR ACHIEVING GOALS

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Human Exploration and Development of Space (HEDS) mission holds for students and educators. The unique character of the Human Exploration and Development of Space (HEDS) Strategic Enterprise's exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with the Human Exploration and Development of Space (HEDS) Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of HEDS activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

The Human Exploration and Development of Space (HEDS) Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating HEDS Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students underrepresented in NASA-related fields who, because of their

research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the HEDS Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

The Office of Life and Microgravity Sciences and Applications (OLMSA) is also making a contribution to academic programs as part of the HEDS Enterprise. Details can be found in the Life and Microgravity Sciences and Applications section.

SCHEDULE AND OUTPUTS

Extensive detail as to how this funding is utilized is located under the Academic Programs portion of the budget.

ACCOMPLISHMENTS AND PLANS

Extensive detail as to how this funding is utilized is located under the Academic Programs portion of the budget.

BASIS OF FY 2001 FUNDING REQUIREMENT

TECHNOLOGY AND COMMERCIALIZATION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
HEDS Technology and Commercialization.....	--	--	20,000

PROGRAM GOALS

The goals of the Human Exploration and Development of Space (HEDS) Technology/Commercialization Initiative (HTCI) are four-fold. First, the HTCI will support HEDS analysis and planning for safe, affordable and effective future programs and projects that advance science and discovery, human exploration, and commercial development of space. Second, the Initiative will pursue research, development, and validation of breakthrough technologies and highly innovative systems concepts that open up new and potentially revolutionary system-, infrastructure- and architecture- level options for HEDS. The HTCI will pursue technologies, systems and infrastructures that enable synergistic advancement of science-driven integrated human-robotic space exploration, as well as the commercial development of space. Finally, the Initiative will improve the affordability and the effectiveness with which HEDS will be able to achieve it's strategic objectives in the future by creating strong partnerships within NASA, with US industry and universities, and with international partners. By achieving these goals, the HEDS Technology/Commercialization Initiative will support better informed decisions by policy-makers concerning a) further research and technology development investments, and b) prospective future HEDS exploration initiatives and related capabilities and infrastructures. It will also make high-leverage, high-risk incremental progress toward innovative systems concepts and breakthrough technologies that could support market-driven, private sector decisions concerning commercial development of space.

STRATEGY FOR ACHIEVING GOALS

The strategic approach to accomplish the program goals of the HTCI involves three types of activities. First, HTCI will conduct systems analysis and advanced concept studies. These activities will include the formulation and refinement of new approaches (e.g., architectures, technologies, etc.) and the identification/refinement of advanced systems concepts in order to dramatically increase safety while reducing mission risk and cost for future prospective HEDS programs. Second, the Initiative will undertake HEDS-enabling advanced research and technology (HART) projects. These will be competitively selected (with a goal of 50% cost share from Industry, where appropriate), and will emphasize increases in safety, reduced risks and costs, and enabling new opportunities. Wherever possible, HART Projects will leverage other resources (including investments within NASA, other US government, industry, academia, internationally, etc.). Finally, the HTCI will conduct flight demonstration projects (including small missions, if funding permits). These flight projects will involve "new millennium-type" experiments for small robotic missions, on the International Space Station, or other carriers. This area will include resources for the development of competitively selected HEDS payloads for inclusion in Office of Space Science (OSS) Mars missions, as well as other flight projects that will be competitively selected (with a goal of 50% cost share from Industry, where appropriate).

SCHEDULE AND OUTPUTS

Systems Analysis and Advanced Concepts Studies - Activities supporting System Analysis and Advanced Concepts Studies will be integrated with the NASA Research Announcements (NRAs) supporting HEDS-enabling Advanced Research and Technology (HART) projects, as summarized below.

HEDS-enabling Advanced Research and Technology (HART) Projects

'01HEDS-enabling Research and Technology (HART) NASA Research Announcement Plan: 1st Qtr FY 2001	Initial solicitation of HEDS systems studies and HART technology projects; coordinated with planning for later flight demonstration projects/options.
'01HEDS-enabling Research and Technology (HART) NRA Project Announcements Plan: 3rd Qtr FY 2001	Announcement of awards from initial HART NRA.
'02 HEDS-enabling Research and Technology (HART) NASA Research Announcement Plan: 1st Qtr FY 2002	Second solicitation of HEDS systems studies and HART technology projects; coordinated with planning for later flight demonstration projects/options.

Flight Demonstration Projects

'01HEDS Technology/ Commercialization Initiative NASA Research Announcement for Flight Demonstration Projects Plan: 4th Qtr FY 2001	Initial solicitation of HEDS flight demonstration projects, focusing on demonstration project definition studies; coordinated with HCTI studies and HART technology projects.
'01HEDS Technology/ Commercialization Initiative NRA Flight Demonstration Project Definition Study Announcement Plan: 2nd Qtr FY 2002	Initial solicitation of HEDS flight demonstration projects, focusing on demonstration project definition studies; coordinated with HCTI studies and HART technology projects.

ACCOMPLISHMENTS AND PLANS

During FY 1999 the Office of Space Flight (OSF) Advanced Projects Office (APO) conducted preliminary, largely in-house studies and assessments of human exploration mission and technology options under the funding for the Engineering and Technical Base (ETB). These efforts continued in FY 2000 as reflected in the ETB section of the Launch Vehicles and Payloads Operations budget narrative. During Fiscal Year 2001, the OSF APO will implement the HEDS Technology/Commercialization Initiative, including competitively selected activities and specific in-house activities. Preliminary validation of technologies at the component level will be accomplished, as well as planning for potential future investment options. Flight Demonstration Project options will be defined, as well as implementation of HEDS experiments for the Office of Space Science Mars's missions, as appropriate.

BASIS OF FY 2001 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Engineering and technical base	[90,672]	[79,300]	73,500

PROGRAM GOALS

The focus of the Engineering and Technical Base (ETB) is to support the institutional capability in the operation of space flight laboratories, technical facilities, and testbeds; to conduct independent safety, and reliability assessments; and to stimulate science and technical competence in the United States. ETB activities are carried out at the Johnson Space Center (JSC) including White Sands Test Facility (WSTF), Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), and Stennis Space Center (SSC). ETB funds are used to: maintain the Centers' technical competence and ability to perform research; analysis and testing tasks; to solve present problems; and to reduce costs in developing programs, technologies, and materials. Efforts include system and mission analysis, integrated HSF Research and Technology (R&T) requirements definition and integration, modest R&T investments in an EVA technology demonstration project and investments in R&T required to support the integrated Office of Space Science/HEDS robotic efforts.

STRATEGY FOR ACHIEVING GOALS

The complex and technically challenging programs managed by the Office of Space Flight (OSF), now and in the future, are most effectively carried out by sustaining a NASA "core" institutional technical base. It is vital to preserve essential competency and excellence. Since FY 1994, the OSF centers have consolidated activities and have identified ways to economize the resources committed to ETB while maintaining ETB's benefits to the nation's human space flight program. Over the next few years, this consolidation will continue to generate savings through improved information resources management and contract streamlining. A prioritized core capability will include multi-program labs and test facilities, associated systems, equipment, and a full range of skills capable of meeting research, testing and simulation demands.

Several ETB activities will continue to seek out efficiencies and cost savings, by refining current business practices. Mandatory equipment repair and replacement will be reassessed. Software applications for multi-program analytical tools will be implemented. The strategy to better manage the NASA investment in information processing resources includes aggressive actions to integrate and consolidate more ADP operations. ETB will ensure synergism among major NASA engineering programs. Awards for education and research tasks will be granted to support educational excellence and research learning opportunities in colleges and universities. A key challenge of the ETB strategy will be to provide a core capability for future human space flight endeavors with fewer resources. Adoption of new innovative processes to meet critical ETB core requirements and streamlining or eliminating non-critical capabilities will enable future savings.

SCHEDULE AND OUTPUTS

Laboratories & facilities supported (KSC)	Maintains 11 science and engineering laboratories in support of 6 agency programs
Laboratories & facilities supported (JSC)	Maintains 156 science and engineering laboratories in support of 52 agency programs
Laboratories & facilities supported (MSFC)	Maintains 123 science and engineering laboratories and facilities in support of 42 agency programs
Laboratories & facilities supported (SSC)	Maintains 3 science and engineering laboratories in support of 2 agency programs
NASA Minority University Research and Education Program at JSC, KSC, MSFC & SSC	Award education and research grants

ACCOMPLISHMENTS AND PLANS

In FY 2001, all Space Flight Centers will transition to a Full Cost budget environment. At this time the ETB budget will be phased out. Under Full Cost environment, ETB activities will be planned, justified and budgeted for by the benefiting customer receiving the service. All OSF Centers previously providing these ETB services will define and establish service pools and usage costs in order to recover operating costs. Service pools will be established for testing services, science and engineering laboratory capability, and computer operations. OSF Centers will continue to provide the highest quality science and engineering analyses for NASA's programs and external customers.

In FY 2001, ETB will support establishment of new budget line items for Rocket Propulsion Testing by transferring the portion of ETB budget supporting propulsion testing.

In FY 2001, establishment of a new budget line item for Center investments for facilities, laboratories, and equipment upgrades to maintain a state-of-the-art. A major investment initiative at MSFC is the Advanced Propulsion Research Center that allows us to conduct basic research that will lead to major advances in propulsion technology. In FY 2001 MSFC will maintain ETB's institutional base requirements funding; award education and research grants to Historically Black Colleges and Universities (HBCU) to promote science and technology; maintain highly skilled Safety and Mission Assurance contractor workforce to conduct assessment of conformance to reliability and quality standards; maintain technical core capability to provide in-depth technical support for research, design, development, mission operations, and evaluation; and ETB funding for Propulsion Testing will transfer from MSFC to SSC.

In FY 2001, JSC's efforts will continue to focus on maintaining the multi-program use science and engineering laboratories and facilities operational readiness. This effort will include performing scheduled facility infrastructure sustaining maintenance, maintaining analytical tools readiness, and performing the necessary repairs, modifications, and replacements to the facilities infrastructure to accommodate the changes needed to support program commitments. FY2001 contains many critical programmatic milestones that will require extensive use of our laboratories and facilities. NASA will continue to need to perform critical studies, test, and analyses for many activities. These include: monitoring human life support and crew health as crews continue to inhabit ISS, ensuring the Shuttle can safely operate and transport Station hardware and astronaut personnel, and ensuring smooth and safe operations of personnel and equipment during the Station assembly EVAs. ETB will also keep the laboratories and facilities operational to perform exploration and development studies.

In FY 2001, KSC Materials Science Laboratory will continue providing analysis and test support to Shuttle, Space Station, Reusable Launch Vehicles, Payloads and Life Sciences programs. In the area of technology development, the KSC Materials Science Laboratory will establish Electrostatic Discharge and Corrosion Engineering Testbeds.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The Science, Aeronautics and Technology appropriation provides funding for the research and development activities of NASA. This includes funds to extend our knowledge of the Earth, its space environment, and the universe; and to invest in new aero-space transportation technologies that support the development and application of technologies critical to the economic, scientific and technical competitiveness of the United States.

STRATEGY FOR ACHIEVING GOALS

Funding included in the Science, Aeronautics and Technology appropriation supports the program elements of NASA's four Enterprises:

Human Exploration of Space - uses the microgravity environment of space to conduct basic and applied research to understand the effect of gravity on living systems and to conduct research in the areas of fluid physics, materials science and biotechnology.

Space Science - seeks to answer fundamental questions concerning the galaxy and the universe; the connection between the Sun, Earth and heliosphere; the origin and evolution of planetary systems; and, the origin and distribution of life in the universe.

Earth Science - to understand the total Earth system and the effects of natural and human-induced changes on the global environment.

Aero-Space Technology - to pioneer high-payoff, critical technologies with effective transfer of design tools and technology products to industry and government.

Funding is also included to provide highly reliable, cost effective telecommunications services in support of NASA's science and aeronautics programs, and to conduct NASA's agency-wide university, minority university, and elementary and secondary school programs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
SCIENCE, AERONAUTICS AND TECHNOLOGY	**5,653.9**	**5,580.9**	**5,928.4**
SPACE SCIENCE	2,119.2	2,192.8	2,398.8
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	263.5	274.7	302.4
EARTH SCIENCE	1,413.8	1,443.4	1,405.8
AERO-SPACE TECHNOLOGY	1,198.5	984.9	1,058.0
COMMERICAL TECHNOLOGY	140.3	140.0	135.0
MISSION COMMUNICATION SERVICES	380.0	406.3	-
SPACE OPERATIONS	-	-	529.4
ACADEMIC PROGRAMS	138.5	138.8	100.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

SCIENCE, AERONAUTICS AND TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of science, aeronautics and technology research and development activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,580,900,000] *$5,929,400,000*, to remain available until September 30, [2000] 2001. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Acts, 1999.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1999	FY 2000	FY 2001
SCIENCE, AERONAUTICS AND TECHNOLOGY	**574.4**	**605.5**	**609.1**
SPACE SCIENCE	52.5	74.0	55.3
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	0.5	1.5	0.5
EARTH SCIENCE	442.1	425.6	399.7
AERO-SPACE TECHNOLOGY	63.3	72.6	66.0
COMMERICAL TECHNOLOGY	8.2	9.6	9.4
MISSION COMMUNICATION SERVICES	7.7	22.1	--
SPACE OPERATIONS	--	--	78.2
ACADEMIC PROGRAMS	0.1	0.1	-

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 ESTIMATES

DISTRIBUTION OF SCIENCE, AERONAUTICS, AND TECHNOLOGY BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Space Science	1999	2,119,200	19,858	201,321	181,230	0	105,343	30	19,935	27,379	741,721	708,730	113,653
	2000	2,192,785	16,466	145,193	147,346	35	103,556	75	12,118	24,323	764,738	825,000	153,935
	2001	2,398,800	25,442	185,568	126,137	35	117,619	75	18,524	22,504	870,508	985,193	47,195
Life and Microgravity Sciences and Applications	1999	263,500	76,999	5,808	63,613	0	34,099	0	429	38,891	11,069	12,881	19,711
	2000	274,721	94,458	5,465	53,163	0	32,651	0	52	39,377	10,324	10,484	28,747
	2001	302,400	124,109	4,559	61,387	0	36,185	0	35	37,348	6,776	13,988	18,013
Earth Science	1999	1,413,800	5,520	65,584	30,141	39,491	15,868	16,432	74,073	0	882,418	247,300	36,973
	2000	1,443,425	5,005	73,044	35,550	32,845	17,394	20,500	87,047	0	895,380	248,174	28,486
	2001	1,405,800	4,595	88,005	37,593	36,290	15,559	20,450	101,667	0	811,664	248,492	41,485
Aero-Space Technology	1999	1,198,548	5,492	1,779	317,429	22,774	205,818	86,581	280,983	221,599	4,478	6,111	45,504
	2000	984,849	2,025	4,446	191,745	29,658	197,034	98,521	198,913	186,187	1,227	4,072	71,021
	2001	1,058,000	5,667	10,555	236,574	10,760	211,477	99,224	237,734	194,870	3,781	10,452	36,906
Commercial Technology Programs	1999	140,352	14,725	7,398	20,075	3,638	11,994	3,619	17,413	23,321	30,411	3,082	4,676
	2000	140,005	15,473	6,111	20,874	3,704	13,329	3,659	17,167	23,953	30,849	2,916	1,970
	2001	135,000	14,393	5,466	20,536	4,986	13,238	4,941	16,087	21,129	29,338	2,916	1,970
Total Aero-Space Technology	1999	1,338,900	20,217	9,177	337,504	26,412	217,812	90,200	298,396	244,920	34,889	9,193	50,180
	2000	1,124,854	17,498	10,557	212,619	33,362	210,363	102,180	216,080	210,140	32,076	6,988	72,991
	2001	1,193,000	20,060	16,021	257,110	15,746	224,715	104,165	253,821	215,999	33,119	13,368	38,876
Mission Communication Services	1999	380,000	119,700	0	300	0	0	12,600	0	10,100	101,800	132,400	3,100
	2000	406,300	171,900	1,100	1,400	0	0	12,800	0	10,100	71,800	131,900	5,300
	2001	0	0	0	0	0	0	0	0	0	0	0	0
Space Operations	1999	0	0	0	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0	0	0	0
	2001	529,400	222,300	41,700	11,900	0	0	12,600	0	9,000	94,600	131,100	6,200
Academic Programs	1999	138,500	4,603	6,792	10,144	3,513	6,426	2,619	4,460	14,476	69,933	3,314	12,220
	2000	138,810	2,672	3,834	8,300	2,742	4,279	1,756	2,300	6,239	90,247	2,264	14,177
	2001	100,000	2,921	3,738	8,150	2,480	4,326	1,712	2,200	6,865	52,031	1,319	14,258
TOTAL SCIENCE, AERONAUTICS AND TECHNOLOGY	1999	5,653,900	246,897	288,682	622,932	69,416	379,548	121,881	397,293	335,766	1,841,830	1,113,818	235,837
	2000	5,580,895	307,999	239,193	458,378	68,984	368,243	137,311	317,597	290,179	1,864,565	1,224,810	303,636
	2001	5,929,400	399,427	339,591	502,277	54,551	398,404	139,002	376,247	291,716	1,868,698	1,393,460	166,027

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE **SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
* Chandra X-ray Observatory	45,300	4,100	--	SAT 1-6
* Space Infrared Telescope Facility	119,700	123,400	117,600	SAT 1-8
* Hubble Space Telescope (Development)	159,600	160,100	168,100	SAT 1-11
* Relativity (GP-B) Mission	61,300	49,900	13,800	SAT 1-14
* Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics	53,300	27,500	--	SAT 1-17
* Stratospheric Observatory For Infrared Astronomy	58,200	39,000	33,900	SAT 1-19
Payload and Instrument Development	29,200	13,600	7,100	SAT 1-22
* Explorers	205,100	122,300	138,800	SAT 1-27
* Discovery	123,900	154,800	196,800	SAT 1-35
* Mars Surveyor	227,700	248,400	326,700	SAT 1-40
Mission Operations	117,300	75,400	80,000	SAT 1-44
Supporting Research and Technology	916,100	1,179,285	1,302,800	SAT 1-50
Investments	--	--	13,200	SAT 1-80
Construction of Facilities	2,500	--	--	
Undistributed Reduction	--	-5,000	--	
Total	2,119,200	2,192,785	2,398,800	

*Total Cost information is provided in the Special Issues section

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2001 ESTIMATES

BUDGET SUMMARY

Distribution of Program Amount by Installation	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Johnson Space Center	19,858	16,466	25,442
Kennedy Space Center	201,321	145,193	185,568
Marshall Space Flight Center	181,230	147,346	126,137
Ames Research Center	105,343	103,556	117,619
Langley Research Center	19,935	12,118	18,524
Glenn Research Center	27,379	24,323	22,504
Goddard Space Flight Center	741,721	764,738	870,508
Jet Propulsion Laboratory	708,730	825,000	985,193
Dryden Flight Research Center	30	75	75
Stennis Space Center	0	35	35
Headquarters	113,653	153,935	47,195
Total	2,119,200	2,192,785	2,398,800

PROGRAM GOALS

Humans have a profound and distinguishing imperative to understand our origin, our existence, and our fate. For millennia, we have gazed at the sky, observed the motions of the Sun, Moon, planets, and stars, and wondered about the universe and the way we are connected to it. The Space Science Enterprise serves this human quest for knowledge. As it does so, it seeks to inspire our Nation and the world, to open young minds to broader perspectives on the future, and to bring home to every person on Earth the experience of exploring space.

The mission of the Space Science Enterprise is to solve mysteries of the universe, explore the solar system, discover planets around other stars, and search for life beyond Earth; from origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets, and life. In pursuing this mission, we develop, use, and transfer innovative space technologies that provide scientific and other returns to all of NASA's Enterprises, as well as globally competitive economic returns to the Nation. We also use our knowledge and discoveries to enhance science, mathematics, and technology education and the scientific and technological literacy of all Americans.

In accomplishing its mission, the Space Science Enterprise addresses most directly the following NASA fundamental questions:

> How did the universe, galaxies, stars, and planets form and evolve? How can our exploration of the universe and our solar system revolutionize our understanding of physics, chemistry, and biology?
>
> Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

The four long-term goals of the Space Science Enterprise are:

> Establish a virtual presence throughout the solar system, and probe deeper into the mysteries of the universe and life on Earth and beyond—a goal focused on the fundamental science we will pursue;
>
> Pursue space science programs that enable, and are enabled by, future human exploration beyond low-Earth orbit—a goal exploiting the synergy with the human exploration of space;
>
> Develop and utilize revolutionary technologies for missions impossible in prior decades—a goal recognizing the enabling character of technology; and
>
> Contribute measurably to achieving the science, mathematics, and technology education goals of our nation, and share widely the excitement and inspiration of our missions and discoveries—a goal reflecting our commitment to education and public outreach.

STRATEGY FOR ACHIEVING GOALS

Science

The Space Science Enterprise pursues the study of origins, as well as studies of the evolution and destiny of the cosmos, by establishing a continuum of exploration and science. It creates a virtual presence in the solar system, exploring new territories and investigating the solar system in all its complexity. It simultaneously probes the universe to the beginning of time, looking ever deeper with increasingly capable telescopes, scanning the entire electromagnetic spectrum from gamma rays to radio wavelengths. It also sends probes into interstellar space, beginning a virtual presence even beyond the solar system.

The strategy of the Enterprise is to conduct world-class research, to maximize the scientific yield from our current missions, and to develop and deploy new missions within the "faster, better, cheaper" framework of a revolutionized NASA.

A key aspect of our strategic planning is to ensure the Enterprise acquires the advice of the external science community, and in particular the National Academy of Sciences. The Enterprise is also ensuring science community input by utilizing peer review in

the Discovery, Explorer and Supporting Research and Technology programs. In addition, there is extensive collaboration with this community, international partners, and other federal agencies, such as the National Science Foundation, Department of Defense, and Department of Energy, in the conduct of our missions, research and technology.

As a visible link to future human exploration beyond Earth orbit, Space Science Enterprise robotic missions help develop the scientific knowledge such ventures will need. In the long term, the Enterprise will benefit from the opportunities human exploration will offer to conduct scientific research that may stretch beyond the capabilities of robotic systems.

Education and public outreach

The traditional role of the Space Science Enterprise in supporting graduate and postgraduate professional education — a central element of meeting our responsibility to help create the scientific workforce of the future — is being expanded to include a special emphasis on pre-college education and on increasing the public's knowledge, understanding, and appreciation of science and technology. The comprehensive approach to education and public outreach developed by the Space Science Enterprise is described in more detail in the October 15, 1996 report "Implementing the Office of Space Science Education/Public Outreach Strategy", available in full on the World Wide Web at http://spacescience.nasa.gov/edu/imp_plan.htm

Our strategy begins with incorporating education and public outreach as an integral component of all of our activities — flight missions and research programs. It focuses on identifying and meeting the needs of educators and on emphasizing the unique contributions the Space Science Enterprise can make to education and to enhancing the public understanding of science and technology. It is directed toward: optimizing the use of limited resources; encouraging a wide variety of education and outreach activities; channeling individual efforts towards high-leverage opportunities; developing high-quality education and outreach activities and materials having local, state, regional, and national impact; and ensuring that the results of our education programs are catalogued, evaluated, archived and widely disseminated. Our strategy supports NASA's overall education program and is aligned with NASA's efforts to ensure that participation in NASA missions and research programs is as broad as possible. It is centered on brokering and facilitating the formation of partnerships between space scientists and a wide range of individuals and institutions across the country engaged in education and in communicating science and technology to the public. It makes contributing to education and outreach the collective responsibility of all levels of management in the Space Science Enterprise and all the participants in the Space Science program.

During FY 2001, we will successfully achieve at least six of the following eight objectives:

(1) Every mission initiated in FY 2001 will have a funded education and outreach program with a comprehensive education and outreach plan prepared by its Preliminary Design Review (PDR).
(2) By the end of FY01, 10 percent of all research grants will have a funded education and outreach program underway.
(3) Enterprise-funded education and outreach activities will be in planning or implementation in at least 34 states.
(4) At least five Enterprise-funded research, mission development or operations, or education projects will be underway in Historically Black Colleges and Universities, Hispanic Serving Institutions and Tribal Colleges, with at least one being underway in an institution of each type.

(5) The Enterprise will provide exhibits, materials, workshops, and personnel at a minimum of five national and three regional education and outreach conferences.
(6) At least five major Enterprise-sponsored exhibits or planetarium shows will be on display or on tour at major science museums or planetariums across the country.
(7) The first comprehensive Space Science Enterprise Education/Outreach Report will be prepared that describes participants, audiences, and products for Enterprise education and outreach programs.
(8) Initial results of a pilot assessment of the Enterprise's approach to education and outreach will be available for determining whether adjustments in program direction or organization are needed.

Technology development and transfer
A number of enabling technologies have been identified for the Space Science program, and prioritizing them is one of the most important technology planning tasks. These technologies fall into two general categories:

- Technologies that provide fundamental capabilities without which certain objectives cannot be met, or that open completely new mission opportunities. Fundamental enabling capabilities include developments such as high-precision deployable structures that maintain optical paths to within fractions of a wavelength of light. These are required for studying extra-solar planets through optical interferometry, as well as for the next generation of large space telescopes that will see to the edge of the Universe.

- Technologies that reduce cost and/or risk to such a degree that they enable missions that would otherwise be economically unrealistic. Highly capable micro-electronics and micro-spacecraft systems, by virtue of their broad applicability and potential for reducing mission costs and development times, enable missions which would otherwise be prohibitively expensive. The importance of these systems and their commercial potential make them one of our most important technology investment areas.

A well-structured technology portfolio must recognize and balance the importance of both categories. A key aspect of this portfolio is that it utilizes partnerships with industry, other government agencies and universities in the planning, development and implementation of Space Science missions. Many capabilities have been transferred and infused into industry from DoD or NASA core technology support, and the space science research community uses the resulting industrial space infrastructure for mission planning and development. Industry partnerships allow for a more efficient linkage between the builders and users of flight hardware. The identification, development and utilization of advanced technology dramatically lowers instrument, spacecraft, and mission operations costs and contributes to the long-term capability and competitiveness of American industry.

BASIS OF FY 2001 FUNDING REQUIREMENT

CHANDRA X-RAY OBSERVATORY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Chandra X-ray Observatory development *	45,300	4,100	

* Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Chandra X-ray Observatory (CXO, formerly the Advanced X-ray Astrophysics Facility, AXAF) is the third of NASA's Great Observatories, which include the Hubble Space Telescope and the Compton Gamma Ray Observatory. CXO observes matter at the extremes of temperature, density and energy content. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, CXO is providing unique and crucial information on the nature of objects ranging from nearby stars to quasars at the edge of the observable universe.

STRATEGY FOR ACHIEVING GOALS

The Marshall Space Flight Center (MSFC) was assigned responsibility for managing AXAF in 1978 as a successor to the High Energy Astrophysics Observatory (HEAO) program. The scientific payload was selected through an Announcement of Opportunity (AO) in 1985 and confirmed for flight readiness in 1989.

The AXAF program was restructured in 1992 in response to decreasing future funding projections for NASA programs. The original baseline was an observatory with six mirror pairs, a 15-year mission in low-Earth orbit, and shuttle servicing. The restructuring produced AXAF-I, an observatory with four mirror pairs to be launched into a high-Earth orbit for a five-year lifetime, and AXAF-S, a smaller observatory flying an X-Ray Spectrometer (XRS). A panel from the National Academy of Sciences (NAS) endorsed the restructured AXAF program. The FY 1994 AXAF budget was reduced by Congress, resulting in termination of the AXAF-S mission. The Committees further directed that residual FY 1994 AXAF-S funds be applied towards development of a similar instrument for flight on the Japanese Astro-E mission. Astro-E is scheduled to be launched by Japan in February 2000.

In December 1998 NASA announced that AXAF had been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. CXO was launched successfully by the Space Shuttle and an Inertial Upper Stage on July 23, 1999.

SCHEDULE & OUTPUTS

Launch Observatory Plan: August 1998 Actual: July 23, 1999	Shuttle deployment into low-Earth orbit followed by upper stage delivery to highly elliptical operational orbit. Delayed by need for additional testing and review to ensure mission success.

ACCOMPLISHMENTS AND PLANS

CXO was successfully launched on July 23, 1999. The Observatory has achieved its final science orbit. Launch in July 1999 was an eleven-month slip vs. the original target date. The FY 1999 budget increased by $45.3 million; FY 2000 increased by $4.1 million; adding prior increases of $7.0 million, the total program increase is $56.4 million (about 3.5%).

Following launch, the spacecraft entered a period of checkout, followed by the start of science operations. The observatory is functioning well, and initial results have been very gratifying. Current information is available on the project web site at http://chandra.harvard.edu/index.html.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE INFRARED TELESCOPE FACILITY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
SIRTF development *	119,700	123,400	117,600

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Space Infrared Telescope Facility (SIRTF) mission is to explore the nature of the cosmos through the unique windows available in the infrared portion of the electromagnetic spectrum. These windows allow infrared observations to explore the cold Universe by looking at heat radiation from objects which are too cool to radiate at optical and ultraviolet wavelengths; to explore the hidden Universe by penetrating into dusty regions which are too opaque for exploration in the other spectral bands; and to explore the distant Universe by virtue of the cosmic expansion, which shifts the ultraviolet and visible radiation from distant sources into the infrared spectral region. To exploit these windows requires the full capability of a cryogenically-cooled telescope, limited in sensitivity only by the faint infrared glow of the interplanetary dust.

Rather than simply "descoping" the original Titan-class SIRTF -- the original "Great Observatory" concept -- to fit within a $400 million (FY 1994 constant dollars) cost ceiling imposed by NASA, scientists and engineers have instead redesigned SIRTF from the bottom-up. With an eye towards cost, and in recognition of the unprecedented sensitivity afforded by the latest arrays, the SIRTF Science Working Group identified a handful of the most compelling problems in modern astrophysics for which SIRTF could make unique and important contributions. These primary science themes, which have received the endorsement of the National Research Council's Committee on Astronomy and Astrophysics, satisfy most of the major scientific themes outlined for the original SIRTF mission in the "Bahcall Report" (which judged SIRTF the highest priority major new program for all of U.S. astronomy in the 1990s).

SIRTF is optimized to attack the scientific questions listed below. The first four questions identify the four primary science programs of the SIRTF mission. The fifth question identifies the potential for serendipitous discoveries using SIRTF.

1. How do galaxies form and evolve? SIRTF's deep surveys will determine how the number and properties of galaxies changed during the earliest epochs of the Universe.

2. What engine drives the most luminous objects in the Universe? SIRTF will study the evolution with cosmic time of the ultraluminous galaxies and quasar populations and probe their interior regions to study the character of their energy sources.

3. Is the mass of the Galaxy hidden in sub-stellar objects and giant planets? SIRTF will search for cold objects with mass less

than 0.08 that of the Sun, not massive enough to ignite nuclear reactions, which may contain a significant fraction of the mass of the Galaxy.

4. Have planetary systems formed around nearby stars? SIRTF will determine the structure and composition of disks of material around nearby stars whose very presence implies that these stars may harbor planetary systems.

5. What lies beyond? SIRTF's greater than 1000-fold gain in astronomical capability beyond that provided by previous infrared facilities gives this mission enormous potential for the discovery of new phenomena.

While these scientific objectives drive the mission design, SIRTF's powerful capabilities have the potential to address a wide range of other astronomical investigations. SIRTF should be able to achieve many of the initial goals of the Origins program; SIRTF's measurements of the density and opaqueness of the dust disks around nearby planets will help set the requirements for future Origins missions designed to directly detect planets.

STRATEGY FOR ACHIEVING GOALS

The Jet Propulsion Laboratory (JPL) was assigned responsibility for managing the SIRTF project. The SIRTF Mission is composed of six major system elements and components as described below. The first three elements (the Science Instruments, Cryo/Telescope Assembly, and Spacecraft Assembly) will be assembled into a single space-based observatory system by means of the fourth element -- System Integration and Test. The fifth element is the launch vehicle, and the sixth is the ground system, which will be used to operate the Observatory on the ground prior to launch, and in space, to achieve the mission objectives.

Science Instruments are being provided by three Principal Investigators (PIs) selected by NASA in 1984 in response to a NASA Announcement of Opportunity. The three science instruments and their PIs are: the Infrared Array Camera (IRAC), Smithsonian Astrophysical Observatory, Dr. Giovanni Fazio; the Infrared Spectrometer (IRS), Cornell University, Dr. James Houck; and the Multiband Imaging Photometer for SIRTF (MIPS), University of Arizona, Dr. George Rieke.

The Cryo/Telescope Assembly (CTA) is being developed by Ball Aerospace and Technologies Corporation, Boulder, CO, as an industrial member of the SIRTF Integrated Project Team. The CTA consists of all of the elements of SIRTF that will operate in space at reduced or cryogenic temperatures, including the telescope, telescope cover, cryostat, and supporting structures and baffles. The cryostat contains the cold portions of the PI-provided Science Instruments.

The Spacecraft Assembly is being developed by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. The spacecraft assembly consists of all of the elements of SIRTF that are needed for power, data collection, Observatory control and pointing, and communications. These elements of SIRTF are nominally operated at or near 300 degrees Kelvin, and also include the warm portions of the PI-provided Science Instruments.

System Integration and Test (SIT) has been identified as a separate system element, and is being provided by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. This element will complete the

assembly of the Observatory using the science instruments, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF will be performed by this element.

Flight and Science and Operations System development is being accomplished in parallel with Observatory development. This has been done to reduce redundant development of ground equipment and software and to assure compatibility between the ground systems and the Observatory after launch. The Flight Operations segment (FOS) is being developed by the mission development team at JPL. The Science Operations Segment (SOS) is being developed by the SIRTF Science Center located at California Institute of Technology's (Cal Tech) Infrared Processing Analysis Center (IPAC).

SIRTF is planned for launch on a Delta 7925-H launch vehicle in December 2001.

SCHEDULE & OUTPUTS

Instrument Development Plan: April 2000	Deliver the Infrared Array Camera (IRAC), Multiband Imaging Photometer (MIPS), and Infrared Spectrograph (IRS) instruments. The instruments will perform at their specification levels at delivery.
Complete Spacecraft Plan: 2nd Qtr, FY 2001	Complete the SIRTF Spacecraft and have it ready for integration with Cryogenic Telescope Assembly (CTA).
Complete CTA Plan: 2nd Qtr, FY 2001	Complete the SIRTF Cryogenic Telescope Assembly (CTA), and deliver it to spacecraft contractor for integration with spacecraft.

ACCOMPLISHMENTS AND PLANS

SIRTF completed its spacecraft bus structure on schedule in May 1999. Delivery of all of the instrument focal plane arrays was completed on schedule in September 1999. The flight model of the cryostat was completed on schedule in October 1999. Delivery of the instruments will be completed by April 2000 to enable integration of the Cryo/Telescope Assembly late in the fiscal year. The spacecraft and the CTA will be completed and ready for integration in the second quarter of FY 2001.

BASIS OF FY 2001 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Hubble Space Telescope Development.....	159,600	160,100	168,100

PROGRAM GOALS

The goal of the Hubble Space Telescope (HST) development activity is to provide new flight hardware, subsystems, and instruments to extend the telescope's operational life and to enhance its capabilities. HST was launched in April 1990 aboard the Space Shuttle. It is the first and flagship mission of NASA's Great Observatories program, and it is designed to complement the wavelength capabilities of the other spacecraft in the program (CGRO, CXO, and SIRTF). HST is the only one of those observatories that can be serviced and upgraded on orbit. HST is a 2.4-meter telescope capable of performing observations at visible, near-ultraviolet, and near-infrared wavelengths. This program is a joint endeavor of NASA and the European Space Agency (ESA), which provided the faint object camera and the HST's solar arrays. HST is a general observer facility with a worldwide user community.

STRATEGY FOR ACHIEVING GOALS

HST was designed to be serviceable and requires on-orbit maintenance and replacement of spacecraft subsystems and scientific instruments about every three years. Ongoing modification and upkeep of system ground operations are also performed. HST was designed for a minimum 15-year mission; current plans call for the final servicing mission to occur around 2003, and for the spacecraft to operate beyond that time until around the year 2010 or until it fails.

The mission was troubled soon after launch by the discovery that the primary mirror was spherically aberrated. In addition, problems with the solar panels flexing as the spacecraft passed from the Earth's shadow into sunlight caused problems with the pointing stability. These problems limited HST's capabilities, but it still took observations and generated many scientific discoveries prior to the correction of those problems during the First Servicing Mission in December 1993. That mission included replacement of the solar panels, replacement of the Wide Field and Planetary Camera with a second-generation version with built-in corrective optics, and replacement of the High-Speed Photometer with COSTAR (Corrective Optics Space Telescope Axial Replacement) to correct the aberration for the remaining instruments. The mission was a complete success.

The Second HST Servicing Mission occurred in February 1997. The crew accomplished the following tasks: replaced a failed Fine Guidance Sensor (FGS); swapped one of the reel-to-reel tape recorders with a solid-state recorder; and exchanged two of the original instruments (the Goddard High-Resolution Spectrograph and the Faint Object Spectrograph) with two new instruments, the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). In addition to this

planned work, astronauts discovered that some of the insulation around the light shield portion of the telescope had degraded and they attached several thermal insulation blankets to correct the problem.

The Third HST Servicing Mission, previously scheduled for May 2000, has been split into two missions: Servicing Missions 3A and 3B. Servicing Mission 3A in December 1999 successfully replaced portions of HST's pointing system, flight computer, and other components. Servicing Mission 3B in 2001 will install the new Advanced Camera for Surveys (ACS) science instrument, a new set of solar arrays, a cooling system to extend the life of the Near Infrared Camera / Multi-Object Spectrometer (NICMOS) instrument, and make other repairs.

The fourth HST Servicing Mission (SM-4) is tentatively scheduled for 2003. Although plans for SM-4 are very preliminary at this time, two science instruments are scheduled for installation. The Cosmic Origins Spectrograph (COS) is a medium resolution spectrograph specifically designed to observe into the near and mid ultraviolet. The ultraviolet region is particularly interesting for observing high energy activities such as are found in new hot stars and Quasi Stellar Objects (QSO's). The Wide Field Camera Three (WFC3) will be HST's last main imaging camera. WFC3 will be a replacement for WF/PC-2 to maintain the quality of imaging capabilities throughout the life of the HST mission.

Following SM-4, HST will continue to operate until 2010, or until subsystem failures render the Observatory inoperable.

SCHEDULE & OUTPUTS

Observatory Upgrades/SM-3 Plan: May 2000 Actual/Revised: December 1999 & July 2001	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B by July 2001.
HST SM-3A Plan: October 1999 Actual: December 1999	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B by July 2001. SM-3A replaced all six gyroscopes, the spacecraft computer, and other hardware items.
HST SM-3B Plan: July 2001	Install two key HST upgrades on Servicing Mission 3B: Advanced Camera for Surveys (ACS) and Solar Array 3 (SA3).

ACCOMPLISHMENTS AND PLANS

HST Servicing Mission 3A was successfully completed, and HST has returned to science operations at the forefront of astronomical research. All plans for Servicing Mission 3B are on track, with the mission currently scheduled for May 2001. Testing of the Advanced Camera for Surveys (ACS) science instrument, the replacement solar arrays, and other components is ongoing. Deliveries of completed units to GSFC for final testing will begin in the latter half of FY 2000.

In preparing for SM4, the initial design, fabrication and assembly of the COS will be completed early in 2000, after which it will enter a period of integration and testing extending through FY 2001. WFC3 initial design, fabrication and assembly have begun, and are expected to continue through late FY 2001. The mission is currently scheduled for June 2003.

BASIS OF FY 2001 FUNDING REQUIREMENT

RELATIVITY MISSION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
GP-B Development *	61,300	49,900	13,800

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. This is the most accepted theory of gravitation and of the large-scale structure of the Universe. General relativity is a cornerstone of our understanding of the physical world, and consequently of our interpretation of observed phenomena. However, it has only been tested through astronomical observation and Earth-based experiments. An experiment is needed to explore more precisely the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect". The dragging of space has never been measured, and the geodetic effect needs to be measured more precisely. Whether the experiment confirms or contradicts Einstein's theory, its results will be of the highest scientific importance. The measurements of both the frame dragging and geodetic effects will allow Einstein's Theory to be either rejected or given greater credence. The effect of invalidating Einstein's theory would be profound, and would call for major revisions of our concepts of physics and cosmology.

In addition, the Relativity Mission is contributing to the development of cutting-edge space technologies that are also applicable to future space science missions and transportation systems.

STRATEGY FOR ACHIEVING GOALS

This test of the general theory requires advanced applications in superconductivity, magnetic shielding, precision manufacturing, spacecraft control mechanisms, and cryogenics. The Relativity Mission spacecraft will employ super-precise quartz gyroscopes (small quartz spheres machined to an atomic level of smoothness) coated with a super-thin film of superconducting material (needed to be able to "read-out" changes in the direction of spin of the gyros). The gyros will be encased in an ultra-low magnetic-shielded, supercooled environment (requiring complex hardware consisting of lead-shielding, a dewar containing supercooled helium, and a sophisticated interface among the instrument's telescope, the shielded instrument probe, and the dewar). The system will maintain a level of instantaneous pointing accuracy of 20 milliarcseconds (requiring precise star-tracking, a "drag free" spacecraft control system, and micro-precision thrusters). The combination of these technologies will enable the Relativity Mission to measure: (1) the distortion caused by the movement of the Earth's gravitational field as the Earth rotates west to east; and, (2) the distortion caused

by the movement of the Relativity Mission spacecraft through the Earth's gravitational field south to north, to a level of precision of 0.5 milliarcsecond per year (the width of a human hair observed from 16 miles).

The expertise to design, build and test the Relativity Mission, as well as the detailed understanding of the requirements for the dewar and spacecraft, resides at Stanford University in Palo Alto, CA. Consequently, MSFC has assigned responsibility for experiment management, design, and hardware performance to Stanford. Science experiment hardware development (probe, gyros, dewar, etc.) and spacecraft development are conducted at Stanford in collaboration with Lockheed Martin Missiles and Space Palo Alto Research Laboratory (LPARL). Spacecraft development and systems integration are being performed by Lockheed Martin Missiles and Space. Launch is scheduled for September 2001 aboard a Delta II launch vehicle.

SCHEDULE & OUTPUTS

Flight Probe integrated with Science Instrument Assembly Plan: April 1998 Actual: July 1999	Successful integration of the science instrument (comprised of gyroscopes, telescopes, detection electronics, and gas management) with the probe. Schedule delays have resulted from technical problems in various science instruments and subsystems, especially during detector package assembly and acceptance testing of the flight gyroscopes.
Flight Telescope Delivery Plan: February 1998 Actual: February 1999	Delivery of the custom, fused-quartz star tracking telescope. Schedule was delayed principally by numerous development problems with the Detector Package Assembly.
Payload Flight Verification Plan: February 1999 Revised: July 2000	Complete the payload (dewar, science instrument, and probe) testing and verification. Schedule delay is driven by the need to repair the probe and repeat testing and verification.
Spacecraft Design, Fab, Assy, and Test Plan: March 1999 Revised: June 2000	Complete the spacecraft design, fabrication, assembly, and test. Work has been deliberately slowed to allow more resources to be applied to the payload.
Final integration and test Plan: March 2000 Revised: September 2000 Revised: July 2001	Complete final integration and test of the Gravity Probe-B science payload with the spacecraft. The final integration date has been delayed due to the need to repair the probe after a failure occurred during payload testing
Launch Plan: March 2000 Revised: October 2000 Revised: September 2001	Successful launch and check-out. Launch has been delayed due to development problems cited above.

ACCOMPLISHMENTS AND PLANS

Gravity Probe-B is proceeding toward a September 2001 launch date. The program had previously been attempting to achieve an earlier launch date, but a failure in the flight probe discovered during payload flight verification has eliminated that possibility. The spacecraft is manifested to launch aboard a Delta II. Accomplishments in FY 1999 included completion of the flight telescope in February 1999. Integration of the science instrument was completed in June 1999. Installation of the science instrument in the flight probe was completed in July 1999, and installation of the flight probe into the dewar was completed in August 1999.

In FY 2000, the program expects to repair the flight probe, reinstall the flight probe into the flight dewar, complete payload flight verification testing, and deliver the payload for integration with the spacecraft.

We are expecting a significant cost growth in FY 2001 as a result of the delay from the baseline launch in October 2000 to September 2001. The cost growth is driven by schedule and manpower needs associated with resolving the technical issues that caused the delay. To prevent or mitigate further schedule delays, resources have been shifted from the spacecraft effort, which is well ahead of critical path, to the probe repair and payload integration and test efforts, which are on the critical path. Civil service on-site presence at Stanford has been significantly increased, as has involvement by the External Independent Readiness Review, the GP-B Science Advisory Committee, and the GP-B Dewar Council. NASA is continuing to review Relativity Mission funding requirements and will notify Congress of funding changes as soon as the information becomes available.

BASIS OF FY 2001 FUNDING REQUIREMENT

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
TIMED Development *	53,300	27,500	

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the TIMED mission is to investigate the energetics of the Mesosphere and Lower Thermosphere/Ionosphere (MLTI) region of the Earth's atmosphere (60-180 km altitude). The MLTI is a region of transition in which many important processes change dramatically. It is a region where energetic solar radiation is absorbed, energy input from the aurora maximizes, intense electrical currents flow, and atmospheric waves and tides occur; and yet, this region has never been the subject of a comprehensive, long-term, global investigation. TIMED will provide a core subset of measurements defining the basic states (density, pressure, temperature, winds) of the MLTI region and its thermal balance for the first time. These measurements will be important for developing an understanding of the basic processes involved in the energy distribution of this region and the impact of natural and anthropogenic variations. In a society increasingly dependent upon satellite technology and communications, it is vital to understand the atmospheric variabilities so that the impact of these changes on tracking, spacecraft lifetimes, degradation of materials, and re-entry of piloted vehicles can be predicted. The mesosphere may also show evidence of anthropogenic effects that could herald global-scale environmental changes. TIMED will characterize this region to establish a baseline for future investigations of global change.

STRATEGY FOR ACHIEVING GOALS

The TIMED mission is the first science mission in a planned program of Solar Terrestrial Probes (STP), as detailed in the Space Science Strategic Plan. TIMED is part of NASA's initiative aimed at providing cost-efficient scientific investigations and more frequent access to space. TIMED is being developed for NASA by the Johns Hopkins University Applied Physics Laboratory (APL). The Aerospace Corporation, the University of Michigan, NASA's Langley Research Center with the Utah State University's Space Dynamics Laboratory, and the University of Colorado are providing instruments for the TIMED mission.

TIMED is on schedule and ready for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission. However, due to Jason's inability to meet the May launch date, the TIMED spacecraft is now scheduled for a fall 2000 launch. The program began its 36-month Phase C/D development period in April 1997. TIMED will be a single spacecraft located in a high-inclination, low-Earth orbit with instrumentation to remotely sense the mesosphere/lower thermosphere/ionosphere regions of the Earth's atmosphere. TIMED carries four instruments: the Solar Extreme ultraviolet

Experiment (SEE), the Sounding of Atmospheric using Broadband Emission Radiometry (SABER) infrared sounder, the Global Ultraviolet Imager (GUVI) and the TIMED Doppler Interferometer (TIDI).

SCHEDULE & OUTPUTS

Begin Spacecraft I&T Plan: January 1999 Actual: September 1998	Spacecraft integration and test began ahead of schedule and is expected to end January 2000.
Completion of Instrument Development Plan: June 1999 Actual: August 1999	Complete delivery of all 4 flight instruments to APL.
Launch Plan: May 2000 Revised: Fall 2000	TIMED will be delivered on time for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission, and will be completed within 10% of the planned development budget. However, due to Jason's inability to meet the May launch date, the TIMED spacecraft is now scheduled for a fall 2000 launch

ACCOMPLISHMENTS AND PLANS

Spacecraft development was completed in FY 1999. All of the instruments were delivered by September 1999. TIMED will be completed in early 2000 and will be put in storage from March 2000 through July 2000 with launch scheduled for the fall of 2000 due to launch delays in co-manifested Jason spacecraft.

BASIS OF FY 2001 FUNDING REQUIREMENT

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Stratospheric Observatory for Infrared Astronomy	51,200	39,000	33,900
[Construction of Facilities]	[7,000]		

PROGRAM GOALS

The primary objective of the SOFIA program is to make fundamental scientific discoveries and contribute to our understanding of the universe through gathering and rigorous analysis and distribution of unique infrared astrophysical data. This will be accomplished by extending the range of astrophysical observations significantly beyond that of previous infrared airborne observatories through increases in sensitivity and resolution.

While accomplishing its scientific mission, the SOFIA program will make significant and measurable contributions in meeting national goals for the reform of science, mathematics, and technology education, particularly at the K-16 level, and in the general elevation of scientific and technological literacy throughout the country. In addition, the SOFIA program will identify, develop, and infuse promising new technologies, which will enable or enhance scientific or educational objectives and reduce mission life-cycle costs.

STRATEGY FOR ACHIEVING GOALS

Astronomical research with instrumented jet aircraft has been an integral part of the NASA Physics and Astronomy program since 1965. For relatively low cost, NASA has been able to provide to the science community very quick, global response to astronomical "targets of opportunity." The Stratospheric Observatory For Infrared Astronomy (SOFIA) is a new airborne observatory designed to replace the retired Kuiper Airborne Observatory (KAO). SOFIA consists of a 2.5 m telescope provided by the German Aerospace Center (DLR) integrated into a modified Boeing 747 aircraft. With spatial resolution and sensitivity far superior to the KAO, SOFIA will facilitate significant advances in the study of a wide variety of astronomical objects. The program will build upon a very successful program of flying teachers on the KAO, by using SOFIA to reach out to K-12 teachers as well as science museums and planetaria around the country.

KAO operations were terminated in October 1995; the savings from cessation of KAO operations are an integral element of the funding plan for SOFIA. Development of SOFIA started in FY 1997. In December 1996, NASA selected a team led by the Universities Space Research Association (USRA), Columbia, MD to acquire, develop and operate SOFIA. The Cost-Plus-Incentive and Award Fee-type contract has a base period for development plus one five-year operations cycle. The contract also contains an option period for one additional five-year operations cycle. SOFIA is expected to operate for at least 20 years. The contract is managed by

NASA's Ames Research Center, Mountain View, CA. Other team members include Raytheon Systems Company - Waco, TX; United Airlines, San Francisco; an alliance of the Astronomical Society of the Pacific and The SETI Institute, both of Mountain View, CA; Sterling Software, Redwood City, CA; and the University of California at Berkeley and Los Angeles. The contract called for the selected company to acquire an existing Boeing 747 SP aircraft, design and implement a modification program to accommodate installation of a large infrared telescope (provided by Germany), test and deliver the flying astronomical observatory to NASA, and provide mission and operations support in approximately five-year increments. USRA's proposal called for operating the aircraft out of Moffett Federal Airfield, Mountain View, CA. SOFIA funding includes $7.0 million in FY 1999 Construction of Facilities funds for modification of SOFIA ground support facilities at the Ames Research Center.

SCHEDULE & OUTPUTS

Telescope Assembly Critical Design Review Plan: November 1998 Revised: April 2000	Formal review of the German contractor's concept for implementation of the telescope assembly. Slipped due to delays in the development of the German telescope assembly.
US System Critical Design Review Plan: September 1999 Revised: June 2000	Formal review of the US concept for implementation of the observatory. Slipped due to delays in the development of the German telescope assembly
Install Cavity Door on Fuselage Mockup Plan: 1st Qtr., FY 2001	Complete the installation of the flight cavity door on the 747 SP fuselage mockup with no anomalies that would require redesign.
Complete the 747 Section 46 Mockup Test Activity Plan: June 2000 Revised: 2nd Qtr., FY 2001	Subject to replanning activities, it is anticipated that the U.S. systems CDR will be completed, the fuselage section mockup pathfinder work will be completed, and major aspects of the structural modification of the 747 SP will be underway.
Complete 747 Structural Modification Plan: FY 2001	Complete structural modification of the 747 SP.
Initial Science Flight Plan: November 2002	Initial operational science flight of the observatory. Delayed from initial target date of October 2001 due to delays in German telescope assembly.

ACCOMPLISHMENTS AND PLANS

In FY 1999, substantial progress was made. The U.S. and German PDRs were completed, as were wind tunnel testing and aerodynamic analysis of the modified aircraft. The 747 fuselage section mockup structural modification was completed, paving the way for the start of the fuselage modification on the SOFIA 747 SP. Fabrication of several key telescope elements took place in Germany. Of particular note, the German primary mirror fabrication and lightweighting was completed, reducing the mass of the mirror by 75%.

Also, modifications of the hangar at Moffett Field, CA began in FY 1999. This hangar will ultimately become the SOFIA Science and Mission Operations Center, serving as the "home" for the SOFIA Observatory once it enters science operations.

A major task accomplished in FY 1999 was the re-planning of the overall program, incorporating the delay in the planned delivery of the German telescope.

In FY 2000, the German Telescope Assembly and U.S. systems critical design reviews (CDRs) will be completed, and major aspects of the structural modification of the 747 SP will be underway. Our German partners should also be far along in the fabrication and test of all major elements of the Telescope Assembly.

In FY 2001, it is anticipated that the structural modification of the 747 SP will be completed. In Germany, all elements of the Telescope Assembly hardware should complete fabrication and subsystem testing, in preparation for installation into the SOFIA 747 SP early in FY 2002, at which point overall Observatory-level integration, test, and verification will commence. Initial SOFIA science operations are now planned to start in November 2002.

BASIS OF FY 2001 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Astro-E	6,400		
Rosetta	12,500	6,100	1,400
Cluster-II	5,000	1,000	
Shuttle/International payloads	5,000	6,000	5,200
Spartan	300	500	500
Total	29,200	13,600	7,100

PROGRAM GOALS

Payload and Instrument Development supports development of hardware to be used on international satellites or on Shuttle missions. International collaborative programs offer opportunities to leverage U.S. investments, obtaining scientific data at a relatively low cost. Shuttle missions utilize the unique capabilities of the Shuttle to perform scientific experiments that do not require the extended operations provided by free-flying spacecraft. Payload and Instrument Development supports investigations in the Astronomical Search for Origins, Sun-Earth Connections, Structure and Evolution of the Universe, and Exploration of the Solar System science themes.

STRATEGY FOR ACHIEVING GOALS

In the FY 1994 appropriation, Congress directed NASA to pursue flight of a GSFC-developed X-ray spectrometer on the Japanese Astro-E mission. NASA contributed improved foil mirrors and an X-ray calorimeter derived from the spectrometer previously planned for the canceled AXAF-S mission. This new device will measure the energy of an incoming X-ray photon by precisely measuring the increase in temperature of the detector as the photon is absorbed. The foil mirrors will have a large collecting area, providing approximately 2 arc second resolution. These capabilities will permit an unprecedented study of a wide range of astrophysical sources. Launch is scheduled for February 2000.

The European Space Agency's ROSETTA mission is a cometary mission that will be launched in the year 2003 by an Ariane 5. The satellite will rendezvous with comet Wirtanen, in late 2011, and orbit it while taking scientific measurements. During the cruise phase, the satellite will be given gravity assist maneuvers once by Mars and twice by the Earth. The satellite will also take measurements during fly-bys of two asteroids. U.S involvement in the Rosetta program includes the development of three remote sensing instruments, as well as support for interdisciplinary scientists and a number of U.S. co-investigators.

The Shuttle/International Payloads program supports other international and U.S. development projects, including portions of two instruments flown on Europe's X-ray Mirror Mission (XMM, December 1999); and participation in Europe's International Gamma Ray Astrophysics Laboratory (INTEGRAL, 2001) and Planck (approx. 2007) missions, as well as the instrument and components for the Cluster-II mission

The original Cluster mission, part of the International Solar-Terrestrial Physics program, was lost on June 4, 1996 with the explosion of the Ariane-5 rocket. Reflight of the full mission (Cluster-II) has been approved by the European Space Agency and NASA. The four spacecraft will carry out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions. Launch is scheduled for June 2000 on two Soyuz vehicles.

The ESA XMM satellite has highly sensitive instruments providing broad-band study of the X-ray spectrum. This mission combines telescopes with grazing incidence mirrors and a focal length greater than 7.5 meters with three imaging array instruments and two Reflection Grating Spectrometers (RGS). The U.S. has provided components to the Optical Monitor (OM) and RGS instruments. XMM science is complementary to the U.S. Chandra X-ray Observatory (CXO). XMM's higher through-put (i.e., higher number of photons collected) will allow somewhat better spectroscopy of faint sources, while CXO will excel at high resolution imaging. XMM was launched December 10th 1999 on an Ariane-5 vehicle.

The ESA INTEGRAL mission will perform detailed follow-on spectroscopic and imaging studies of objects initially explored by the Compton Gamma Ray Observatory. Its enhanced spectral resolution and spatial resolution in the nuclear line region will provide a unique channel for the investigation of processes -- nuclear transitions, electron/positron annihilation, and cyclotron emission/absorption -- taking place under extreme conditions of density, temperature, and magnetic field. U.S. participation consists of co-investigators providing hardware and software components to the spectrometer and imager instruments; a co-investigator for the data center; a mission scientist; and a provision for ground tracking and data collection. Launch is expected in FY 2001.

Planck is the third Medium-Sized Mission (M3) of ESA's Horizon 2000 Scientific Program. It is designed to image the anisotropies of the Cosmic Background Radiation Field over the whole sky, with unprecedented sensitivity and angular resolution. Planck will help resolve several cosmological and astrophysical issues by verifying or refuting the assumptions underlying competing theories of the early universe and the origin of cosmic structure. Planck is expected to be launched with the FIRST satellite but will separate and be placed in a different orbit around the second Lagrangian point of the Earth-Sun System. Although formal agreements have not been finalized, NASA expects to contribute hardware elements for the mission in exchange for science participation.

The Spartan program provides reusable spacecraft, which can be flown aboard the Shuttle. These units can be adapted to support a variety of science payloads and are deployed from the Shuttle cargo bay to conduct experiments for a short time (i.e. several hours or days). Payloads are later retrieved, reinstalled into the cargo bay and returned to Earth. The science payload is returned to the mission scientists for data retrieval and possible refurbishment for a future flight opportunity. The Spartan carrier is also refurbished and modified as needed to accommodate the next science payload.

SCHEDULE & OUTPUTS

Astro-E:	
Flight Model Spectrometer Delivery to Japan Plan: July 1997 Actual: January 1999	This task concluded the XRS instrument construction phase and started a period of validation, testing and calibration. This task was completed late, with subcomponents delivered to Japan as completed. Late deliveries have been accommodated by the Japanese within their schedule.
Final Mirror Quadrant Delivery Plan: December 1998 Actual: April 1999	Satisfied NASA's commitment to provide the X-ray mirrors for the mission to Japan. mirrors perform within specification.
Rosetta:	
Start Phase C/D Plan: January 1999 Actual: January 1999	Start of detailed design and fabrication.
Qualification Model Deliveries Plan: May 2000	Deliver the electrical qualification models for the four U.S.-provided instruments to ESA in May 2000 for integration with the Rosetta Orbiter.
Flight Unit Deliveries Plan: 3rd Qtr., FY 2001	Deliver the flight units for the four U.S.-provided instruments or instrument subsystems to ESA.
Cluster-II:	
4th/final flight model instrument set delivered Plan: August 1999 Actual: September 1999	All U.S. hardware was delivered and completed by September 1999.
Instrument Analysis Software and Verification Plan: FY 2000	Complete the development of the Cluster-II instrument analysis software for the one U.S. and five U.S.-partnered instruments before launch and, if launch occurs in FY00, activate and verify the wideband data and U.S. subcomponents after launch.

Other Shuttle/International:

XMM Launch Plan: August 1999 Revised: January 2000 Actual: December 10, 1999	Launched successfully by ESA on Ariane-5 ELV.
INTEGRAL Critical Design Review Plan: June 1999 Actual: December 1999	This ESA program review included the U.S.-provided hardware.
INTEGRAL Operations Readiness Plan: FY 2000	Prepare the INTEGRAL Science Data Center (ISDC) for data archiving and prepare instrument analysis software for the Spectrometer on INTEGRAL (SPI) instrument.
Planck Cooler Test Plan: April 2000	Assemble and successfully test the breadboard cooler for ESA's Planck mission.
Planck Cooler Performance Report Plan: 4th Qtr., FY 2001	Deliver the Preliminary Breadboard Cooler Performance Report.

ACCOMPLISHMENTS AND PLANS

The first quadrant of flight model mirrors for Astro-E was delivered to Japan in December 1997, and the final quadrant was delivered in April 1999. The science instrument hardware has experienced serious technical difficulties and delays, resulting in a slight overrun (about 3% to date). The project is still on schedule for a February 2000 launch. All hardware has been delivered and integration is complete. We continue to work with our Japanese partners to ensure a successful mission.

Implementation of the U.S. Rosetta instruments began in January 1999. Structural-thermal models were delivered at the end of June 1999. The electrical qualification models are being delivered in February 2000, followed by the flight models in January 2001.

Cluster II instrument development activities have progressed very well. Deliveries of the 2nd, 3rd, and 4th Cluster-II flight model sets occurred throughout FY 1999, supporting ESA's June 15, 2000 launch date. All US hardware deliveries were completed on time and within budget.

XMM Flight Model-2 RGS components were delivered to Germany ahead of schedule in March 1998. The U.S. supported integration of instruments onto the spacecraft, and spacecraft integration with the launch vehicle. XMM was successfully launched in December 1999 and has begun orbital operations.

INTEGRAL engineering model instruments were delivered to ESTEC on schedule in May 1998. Work on the flight model will continue through first two quarters of FY 2000; Flight Model delivery is expected February 15, 2000.

Spartan continues as an advanced carrier, which could support Explorer missions, environmental science initiatives, as well as Space Station free-flyers.

EXPLORER PROGRAM

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Far Ultraviolet Spectroscopy Explorer	14,600		
Submillimeter Wave Astronomy Satellite, Transition Region and Coronal Explorer, Wide-field Infrared Explorer	7,800		
Imager for Magnetopause-to-Aurora Global Exploration & Microwave Anisotropy Probe	90,200	34,100	15,100
Student Explorer Demonstration Initiative	3,600	5,000	2,700
High Energy Transient Explorer-II	11,100	3,200	
High Energy Solar Spectroscopic Imager	30,700	20,400	
Galaxy Evolution Explorer	25,500	17,400	17,900
Two Wide-Angle Neutral-Atom Spectrometers	4,700	3,600	1,600
Cosmic Hot Interstellar Plasma Spectrometer	4,100	5,400	3,200
Inner Magnetosphere Explorer	6,000	4,900	2,600
Explorer Planning (All Others)	6,800	28,300	95,700
*Total	205,100	122,300	138,800

*Total cost information is provided in the Special Issues section.

PROGRAM GOALS

The goal of the Explorer Program is to accomplish frequent, high-quality space science investigations utilizing innovative, streamlined, and efficient management approaches. It seeks to substantially reduce mission cost through commitment to, and control of, design, development, and operations costs, as well as to reduce cost and improve performance through the use of new technology. Finally, it seeks to enhance public awareness of, and appreciation for, space science and to incorporate educational and public outreach activities as integral parts of space science investigations. Investigations selected for Explorer projects are usually of a survey nature, or have specific objectives not requiring the capabilities of a major observatory. The Explorers Program develops scientific missions of modest programmatic scope within the following space science themes: Astronomical Search for Origins and Planetary Systems, The Sun-Earth Connection, and Structure and Evolution of the Universe.

STRATEGY FOR ACHIEVING GOALS

Explorer mission development is managed within an essentially level funding profile. New missions are, therefore, subject to the availability of sufficient funding in order to stay within the total program budget. Explorer missions are categorized by size, starting

with the largest, Delta-class, moving down through the Medium-class (MIDEX), the Small-class (SMEX) and the University-class (UNEX) missions. Funding for Explorer launch services and mission studies is also provided within the Explorer budget.

Delta Class

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission, previously planned as the last of the Delta-class missions, was restructured in order to reduce costs and accelerate the launch date from CY 2000 to early CY 1999. Although not a MIDEX mission, FUSE can be seen as a transitional step towards the MIDEX program. The FUSE mission is to conduct high-resolution spectroscopy in the far ultraviolet region. Major participants include the Johns Hopkins University, the University of Colorado, and University of California, Berkeley. Orbital Sciences Corporation was selected by JHU as the spacecraft developer. Canada provided the fine error sensor assembly, and France provided holographic gratings. NASA's Goddard Space Flight Center provided management oversight of this Principal Investigator-managed mission. FUSE launched successfully in June 1999 aboard a Delta-II launch vehicle.

Medium Class

The Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in all OSS themes. The MIDEX investigations are characterized by a definition, development, launch service, and mission operations and data analysis cost not to exceed $140 million (in Fiscal Year 1998 dollars) total cost to NASA. NASA intends to launch one MIDEX mission per year.

In March 1996 NASA selected the first two science missions for the MIDEX program, the Microwave Anisotropy Probe (MAP) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute is developing the IMAGE mission.

In April of 1998 NASA released an Announcement of Opportunity (AO) for MIDEX 3 & 4, and in January 1999 five proposals were selected in the Step-1 selection for detailed four-month feasibility studies. Step-2, or final, selections were made in October 1999, and the Swift Gamma Ray Burst Explorer (Swift) and Full-sky Astrometric Mapping Explorer (FAME) missions have been selected to continue mission formulation activity. The Swift mission, to be launched in the third quarter of FY 2003, is a three-telescope space observatory for studying gamma ray bursts. Dr. Neil Gehrels of NASA's Goddard Space Flight Center will lead the Swift mission. The FAME mission, to be launched in the third quarter of FY 2004, is a space telescope designed to obtain highly precise position and brightness measurements of 40 million stars. Dr. Kenneth J. Johnston of the U.S. Naval Observatory will lead the FAME mission.

Small Class

The Small Explorer (SMEX) program provides frequent flight opportunities for highly focused and relatively inexpensive missions. SMEX investigations are characterized by a total cost to NASA for definition, development, launch service, and mission operations and data analysis not to exceed $71 million (in Fiscal Year 1998 dollars) . It is NASA's intent to launch one Small Explorer mission per year. The Explorer Program Office at GSFC manages mission definition, development, and launch of these SMEX missions.

The Transition Region and Coronal Explorer (TRACE) mission initiated development in October 1994, and launched successfully in April 1998. TRACE is a solar science mission that will explore the connections between fine-scale magnetic fields and their associated plasma structures. The Submillimeter Wave Astronomy Satellite (SWAS) mission initiated development in 1991, and launched successfully in December 1998. The SWAS mission is providing discrete spectral data for study of the water, molecular oxygen, neutral carbon, and carbon monoxide in dense interstellar clouds, the presence of which is related to the formation of stars. The Wide-field Infrared Explorer (WIRE) mission was intended to detect starburst galaxies, ultraluminous galaxies, and luminous protogalaxies. WIRE initiated development in October 1994 and launched in March 1999. However, WIRE could not carry out its intended science objective when its telescope cover ejected prematurely, resulting in the rapid evaporation of the on-board cryogen. WIRE is currently being used as a testbed for technology validation and is making photometric measurements with its precise star trackers.

The High Energy Solar Spectroscopic Imager (HESSI) and the Galaxy Evolution Explorer (GALEX) missions were selected in October 1997 as the next SMEX missions. HESSI will observe the Sun to study particle acceleration and energy release in solar flares. The Galaxy Evolution Explorer (GALEX) is an Ultraviolet Small Explorer mission that will map the global history of the universe through 80 percent of its life. GALEX will probe the causes of star formation during that period in which galaxies evolved dramatically, and most stars, elements, and galaxy disks had their origins. HESSI is being developed by the University of California at Berkeley, and is scheduled for launch on board a Pegasus ELV in July 2000. The GALEX mission is being developed by the California Institute of Technology, with a launch planned for mid-CY 2001.

An Announcement of Opportunity for the next SMEX mission was released in December 1999. A Step-1 selection is planned for 4th Qtr. FY 2000, followed by a Step-2 selection in 3rd Qtr. FY 2001.

Student Explorer Demonstration Initiative and University Class

University-class Explorer (UNEX) missions are ultimately intended to enable a higher flight rate to provide the academic community with routine access to space science research. The UNEX program supports very small, low-cost missions managed, designed and developed at universities, in cooperation with industry. The program will develop greater technical expertise within the academic community beyond the suborbital class missions currently being flown aboard balloons and sounding rockets, thus creating greater opportunity for students and reducing the required role of NASA in-house expertise.

From responses to a UNEX AO released in January 1998, NASA selected Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) and Inner Magnetosphere Explorer (IMEX) in September 1998 as the first set of UNEX missions. CHIPS will use an extreme ultraviolet

spectrograph during its one-year mission to study the "Local Bubble," a tenuous cloud of hot gas surrounding our solar system that extends about 300 light-years from the Sun. CHIPS will be developed by the University of California Berkeley. SpaceDev will build the CHIPS spacecraft. IMEX will study the response of Earth's Van Allen radiation belts to variations in the solar wind. Participants for the IMEX mission include the University of Minnesota, University of Colorado, and Aerospace Corporation. Implementation of both missions has been delayed due to the unavailability of a small launch vehicle and the difficulties of obtaining secondary payload space on larger vehicles.

The UNEX precursor missions under the Student Explorer Demonstration Initiative (STEDI) include the Student Nitric Oxide Experiment (SNOE), Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS), and Cooperative Astrophysics and Technology Satellite (CATSAT). SNOE is a small scientific satellite that is measuring the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE launched successfully in February 1998, and it is now being operated from the mission operations center at the University of Colorado's LASP Space Technology Research building. TERRIERS launched in May 1999. Unfortunately, the spacecraft's attitude control system did not function properly due to software problems, and the mission is no longer operational. CATSAT development is completed, the spacecraft is in storage, awaiting launch opportunity in July 2001.

MISSIONS OF OPPORTUNITY

Missions of Opportunity (MO) were instituted within the Explorer Program as part of the previously mentioned SMEX AO. MO are space science investigations, costing no more than $21 million in FY1998 dollars, that are flown as part of a non-NASA space mission. MO are conducted on a no exchange of funds basis with the organization sponsoring the mission. OSS intends to solicit proposals for MO with all future Explorer AOs.

Under the 1997 SMEX AO, the Two Wide-Angle Neutral-Atom Spectrometers (TWINS) investigation was selected as a MO. TWINS will enable three-dimensional global visualization of Earth's magnetospheric region, thereby greatly enhancing understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. Instruments for the TWINS mission are being developed by Los Alamos National Laboratory (LANL) for launch in 2003 and 2004.

Development is underway for HETE-II, an international (France, Italy and Japan) collaboration, to be launched in June 2000 from Kwajalein Island. HETE-II will seek to obtain precise positions of gamma-ray bursters and other high-energy transient sources. HETE-II is a replacement for HETE-I, which was lost in November 1996 due to launch vehicle third-stage power failures.

SCHEDULE & OUTPUTS

Far Ultraviolet Spectroscopy Explorer (FUSE)

Ship to KSC Plan: September 1998 Revised: April 1999 Actual: April 1999	Shipped on schedule.
Launch Plan: October 1998 Revised: May 1999 Actual: June 1999	Successfully launched June 1999. All spacecraft and instrument subsystems functioning nominally.

Medium-class Explorer Program

IMAGE

Complete S/C Environmental Testing Plan: April 1999 Actual: April 1999	Integrate and test major spacecraft subsystems. Completed.
Delivery, Launch Plan: February 2000	IMAGE will be delivered for an on-time launch.

MAP

Instrument Delivery Plan: 2nd Qtr. CY 1999 Actual: : 2nd Qtr. CY 1999	Complete instrument development and ship for integration with the spacecraft. Completed.
Begin S/C I&T Plan: 3rd Qtr. CY 1999 Actual: : 3rd Qtr. CY 1999	Integrate and test major spacecraft components. Completed.
Begin Environmental Testing Plan: July 2000	Begin system-level environmental testing of the spacecraft.
Delivery, Launch Plan: 1st Qtr., FY 2001	Deliver MAP for launch.

Small-class Explorer Program

WIRE Launch Plan: August 1998 Revised: March 1999 Actual: March 1999	WIRE launched successfully. Mission failed due to the telescope's protective cover being ejected too early, allowing radiation from the Sun to enter the telescope, causing the temperature to rise and the cryogens to boil off. Spacecraft is currently conducting limited science operations using the Star Tracker, and is also being used as a spacecraft control test bed.
HESSI Delivery, Launch Plan: July 2000	HESSI will be delivered in time for a planned July 2000 launch
GALEX Instrument Delivery Plan: July 2000	Deliver the GALEX science instrument from JPL to the Space Astrophysics Laboratory at Caltech during April 2000 for science calibration. The instrument will be fully integrated, functionally tested, and environmentally qualified at the time of the delivery.
Delivery, Launch Plan: 4th Qtr., FY 2001	Deliver GALEX for launch.
TWINS Component Deliveries Plan: March 2000 Revised: 3rd Qtr., FY 2001	Deliver to the Los Alamos National Laboratory in March 2000 all components for system integration and testing of the first flight system for the TWINS mission. The TWINS mission is a payload of opportunity. Scheduled delivery has been delayed to accommodate the schedule of the non-NASA host spacecraft.

University-class Explorer Program

TERRIERS Launch Plan: April 1999 Actual: May 1999	TERRIERS launched successfully in May 1999; however, a flight software error (causing the solar array to point away from the sun) has left the mission unable to meet its science objective.

CATSAT

Launch Plan: 3rd Qtr., FY 1999 Revised: 4th Qtr., FY 2001	Deliver the CATSAT for launch. Delayed due to uncertain launch accommodations.

HETE-II

Launch Plan: December 1999 Revised: June 2000	Complete HETE-II development and launch spacecraft. Launch is currently planned for June 2000. Launch delay is due to approval required for launches from Kwajalein Island and additional testing to ensure mission success.

AO Activities

MIDEX Selection Plan: 4th Qtr. FY 1999 Actual: January 1999	Mission selection, and initiate concept studies. Step-1 selections made in January 1999, and Step-2 selections, SWIFT and FAME, made in October 1999.
Release SMEX AO to industry Plan: 3rd Qtr FY 1999 Actual: December 2, 1999	Release the final AO to industry. Final released to industry December 2, 1999.
SMEX AO Selection Plan: 1st Qtr FY 2000 Revised: 4th Qtr. FY 2000	Mission selection, leading to concept studies.
SMEX Selection Plan: FY 2001	Down-selection (Step 2) for SMEX 8 and SMEX 9.

ACCOMPLISHMENTS AND PLANS

The Explorers Program launched three missions during FY 1999. The Wide-field Infrared Explorer (WIRE) mission in March 1999, the Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS) in May 1999, and the Far Ultraviolet Spectroscopy Explorer (FUSE) in June 1999. Two of the three missions failed, one due to software problems (TERRIERS), and the other to exhaustion of on-board cryogen (WIRE). Currently, the WIRE mission is being used as a technology testbed by other missions to test flight software and other capabilities. Spacecraft and instrument development for the IMAGE,

MAP, HESSI and GALEX missions continued throughout FY 1999. CHIPS completed Phase A, and entered Phase B in September 1999. In September 1998 IMEX entered phase A, which was continued throughout FY99 due to launch vehicle unavailablity. Five MIDEX proposals were selected for Phase A studies in January 1999. CATSAT has completed development, and the spacecraft is in storage awaiting launch opportunity.

The FY 2000 Explorer budget continues to support a full range of mission activities across the various classes of missions. Three missions are targeted for launch in fiscal year 2000: HETE-II in June 2000, IMAGE in February 2000, and HESSI in July 2000. The following activities should be completed during FY 2000 for MAP: spacecraft component and instrument development, subsystem-level testing, and shipment to launch site. SWIFT and FAME were selected as MIDEX-3 and 4 missions in October 1999, and are expected to complete the formulation phase and enter into implementation phase during FY 2000. The GALEX science instrument will be delivered from Jet Propulsion Laboratory (JPL) to the California Institute of Technology for integration and test. An Announcement of Opportunity (AO) for the next SMEX missions was released in December 1999, Step 1 selections will be made in the 4th Quarter of FY 2000. Mission studies and spacecraft and instrument development for the CHIPS and IMEX missions will continue through FY 2000. Missions of Opportunity (MO) include a launch for High Energy Transient Explorer (HETE)-II and continued development of the Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS) mission.

Three missions are targeted for launch in FY 2001: MAP in November 2000, CATSAT in July 2001, and GALEX in September 2001. Full-scale spacecraft and instrument development for the SWIFT and FAME missions will continue throughout FY 2001. Mission studies and spacecraft and instrument development for the CHIPS and IMEX missions will continue through FY 2001, in preparation for launches in 3rd and 4th quarter of FY 2002. Development efforts for the TWINS mission will continue throughout FY01; TWIN-A will launch in FY 2003 and TWIN-B will launch in FY 2004. Step-2 selections for SMEX 8 and 9 missions will be made in the 3rd quarter of FY 2001. Announcements of Opportunity for both UNEX and MIDEX missions will be released in FY01.

BASIS OF FY 2001 FUNDING REQUIREMENT

DISCOVERY PROGRAM

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Stardust *	21,264		
Genesis *	82,894	50,200	7,300
Comet Nucleus Tour *		51,800	45,600
Future Missions	19,742	52,800	135,900
Micromissions			8,000
Total	123,900	154,800	196,800

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Discovery program provides frequent access to space for small planetary missions that will perform high-quality scientific investigations. The program responds to the need for low-cost planetary missions with short development schedules. Emphasis is placed on increased management of the missions by principal investigators. The Discovery program is intended to accomplish its missions while enhancing the U.S. return on its investment and aiding in the national goal to transfer technology to the private sector. It seeks to contain total mission/life-cycle costs and improve performance by using new technology and by controlling design/development and operations costs.. The program also seeks to enhance public awareness of, and appreciation for, space exploration and to provide educational opportunities.

STRATEGY FOR ACHIEVING GOALS

The strategy for the initial set of Discovery missions was to develop each mission spacecraft within a not-to-exceed target cost of $150 million (FY 1992 constant dollars), and a development schedule to launch of no more than three years from start of development. The Discovery micromissions will complement these missions and be assigned cost and development metrics that are equally as challenging.

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory (JPL), and was approved for implementation in October 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. Stardust will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, Stardust carries three additional

scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) was provided by Germany to perform basic compositional analysis of particles encountered in flight; and a dust flux monitor is used to sense particle impacts on the spacecraft. Stardust was launched on a Med-Lite version of the Delta II expendable launch vehicle in February 1999, to rendezvous with the comet in January 2004 and return the samples to Earth in January 2006.

The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. The mission is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA. JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, Genesis will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

The goals of the Comet Nucleus Tour (CONTOUR) mission are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future "new" comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management are provided by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) of Laurel, MD. Launch is expected in June 2002.

In July 1999, two new Discovery missions were selected for pre-implementation planning, Deep Impact and MESSENGER. In October 1999, the first Discovery Mission of Opportunity, ASPERA-3, was approved for implementation. Deep Impact is designed to fire an 1,100-pound (500 kilogram) copper projectile into the comet P/Tempel 1, excavating a large crater more than 65 feet (20 meters) deep, in order to expose its pristine interior ice and rock. The impactor is separated from the flyby spacecraft 24 hours prior to its impact on the surface of the comet. The impactor has an active guidance system that steers it to impact on the sunlit side of the comet surface. The impactor also relays close-up images of the comet's surface prior to impact back to the flyby spacecraft for downlink to Earth. Optical and infrared instruments on the flyby spacecraft image and spectrally map the impact and resulting crater. The Deep Impact mission is led by Principal Investigator, Dr. Michael A'Hearn from the University of Maryland. The flight hardware and ground systems are developed by Ball Aerospace & Technologies Corp. and JPL. Launch is scheduled for January 2004 in order to impact the comet in July 2005.

The Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) mission will send an orbiter spacecraft carrying seven instruments to globally image and study the closest planet to the Sun. MESSENGER will be implemented by a consortium headed by the Principal Investigator, Dr. Sean Solomon of the Carnegie Institution of Washington. MESSENGER will be designed and built by JHU/APL, in collaboration with industrial partners GenCorp Aerojet (propulsion system) and Composite Optics, Inc. (integrated structure). Instruments and instrument subsystems are being supplied by JHU/APL, NASA/Goddard Space Flight Center, the University of Colorado, and the University of Michigan. The Science Team is comprised of Co-Investigators from various institutions. Launch is expected in 2004.

The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) is a Discovery Mission of Opportunity that will provide parts of a scientific instrument to study the interaction between the solar wind and the atmosphere of Mars. It will fly aboard the European Space Agency's Mars Express spacecraft in 2003. The U.S. principal investigator being funded by NASA is Dr. David Winningham of the Southwest Research Institute, San Antonio, TX.

Final selections for the current Discovery AO, released in January, 2000, are expected in 3Q FY 2001. The President's FY 2001 Budget provides additional funding to support a new class of Discovery micromissions that will provide more frequent and varied research opportunities starting with this AO. Discovery micromissions will exploit new mission strategies such as: secondary launch capabilities; flying piggyback on other spacecraft; use of microrover, penetrator, and other micromission capabilities developed for previous NASA missions; or other innovative concepts for very inexpensive solar system science.

SCHEDULE & OUTPUTS

Stardust	
Launch Plan: February 1999 Actual: February 1999	Launched on schedule.
Genesis	
Critical Design Review Plan: May 1999 Actual: July 1999	Confirmation that the mission design is sound. Completed two months late, primarily due to payload design concerns; absorbed out of schedule reserves, with no impact to launch date.
Start Functional Testing Plan: November 1999	Complete Genesis spacecraft assembly and start functional testing. Delayed because of late completion of the Sample Return Capsule and various spacecraft subsystems. Absorbed out of schedule reserves, with no impact to launch date.
Launch Plan: 2nd Qtr., FY 2001	Deliver for launch.
CONTOUR	
Phase B Study Start Plan: October 1998 Actual: April 1999	Start of detailed design studies. Delay did not impact launch schedule.
Preliminary Design Review Plan: 2nd Qtr., FY 2000	Complete a PDR that confirms the design and maintains 15% margins for mass and power.

Complete Imager Breadboard Plan: September 2000	Successfully complete the breadboard of the imager instrument for CONTOUR.
Propulsion System Contract award Plan: FY 2000	Award the contract for the propulsion system following successful PDR.
Critical Design Review Plan: FY 2001	Successful CDR, meeting all program level requirements.
Announcements of Opportunity (AOs)	
Step 2 Selection Plan: 3rd Qtr FY 1999 Actual: July 1999	Phase 2 selection leading to Phase B studies.
AO Release Plan: FY 2000	Release an AO for the next Discovery mission.
Mission Selection Plan: FY 2001	New mission selection.

ACCOMPLISHMENTS AND PLANS

Stardust was launched successfully in February 1999, and is operating well.

During FY 1999, Genesis detailed design activities were completed, leading to the Critical Design Review in July 1999. System-level integration and test activities will occur during FY 2000, with delivery to KSC scheduled for early FY 2001 and launch in January 2001.

The CONTOUR mission started preliminary design activities in FY 1999. The Preliminary Design Review and Confirmation Review are scheduled for January 2000. Assuming that the mission is confirmed, development will start in February 2000, leading to a Critical Design Review in early FY 2001.

A Discovery AO was released in March 1998. In November 1998, candidate Discovery missions were selected for further study, including the first Discovery mission of Opportunity, ASPERA-3. In July 1999 NASA selected MESSENGER and Deep Impact for development. ASPERA-3 received approval to proceed into implementation in October 1999. MESSENGER and Deep Impact will

continue in the formulation phase through FY 2000, leading to Preliminary Design Reviews in FY 2001, followed by confirmation reviews and (potentially) the start of implementation.

The next Discovery AO was released in January 2000. Final selection(s) are expected in 3Q FY 2001. Starting with this AO, the Discovery program will consider micromissions using such potential new strategies as: secondary launch capabilities; flying piggyback on other spacecraft; use of microrover, penetrator, and other micromission capabilities developed for previous NASA missions; or other innovative concepts for very inexpensive solar system science.

BASIS OF FY 2001 FUNDING REQUIREMENT

MARS SURVEYOR PROGRAM

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
1998 Orbiter and Lander	16,958		
2001 Orbiter and Lander	162,204	117,000	34,200
Mars Telecom Network and Science Micromissions		6,000	35,000
Future Missions	48,538	125,400	257,500
Total	227,700	248,400	326,700

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the Mars Surveyor Program is to further our understanding of the atmosphere, surface and subsurface composition and structure, biological potential and possible biological history of Mars, and to search for indicators of past and/or present life there. The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. Missions are planned for launch at every launch opportunity; opportunities occur about every 26 months due to the orbital periods of Earth and Mars. In the near term, missions may either orbit Mars to perform mapping of the planet and its space environment, or actually land on the planet to perform science from the surface. Long-term goals include establishing a sustained presence on Mars and the acquisition and return of carefully selected sample caches. Early missions will facilitate sample returns by identifying those areas of Mars most likely to contain samples of scientific importance, including (potentially) evidence of past biological activity. Missions will also build on one another to support a sustained presence on Mars by emplacing infrastructure at the planet that enhances the science return and overall success of future missions.

STRATEGY FOR ACHIEVING GOALS

This program began in FY 1994 with the development of the Mars Global Surveyor, an orbiter that will obtain much of the data that would have been obtained from the Mars Observer mission. The orbiter carries a science payload, comprised of 6 of 8 spare Mars Observer instruments, aboard a small, industry-developed spacecraft. MGS was launched successfully in November 1996 aboard a Delta II launch vehicle and arrived at Mars in September 1997.

The '98 Mars Orbiter and Lander consisted of the Mars Climate Orbiter (MCO) and the Mars Polar Lander (MPL). The MCO mission was intended to provide information about the cycles of water, carbon dioxide, and dust on Mars. MCO was intended to study the planet's weather for one Martian year, acquiring data to help scientists better understand the Martian climate. The MPL was to

focus primarily on Mars' climate and water. The MPL mission would search for near-surface ice and possible surface records of cyclic climate change, and characterize physical processes key to the seasonal cycles of water, carbon dioxide and dust on Mars. MCO launched in December 1998 and MPL launched in January 1999; however, both missions failed upon arrival at Mars.

In light of the failed MCO and MPL, the entire Mars Surveyor Program is undergoing major re-planning activity. Detail on the revised schedules and outputs will be provided once the re-planning is completed.

The Mars '01 mission was to consist of an Orbiter, a Lander and a Rover. The Orbiter would carry three science instruments, the Thermal Emission Imaging System (THEMIS), the Gamma Ray Spectrometer (GRS), and the Mars Radiation Environment Experiment (MARIE). THEMIS would map the mineralogy and morphology of the Martian surface, GRS would globally map the elemental composition of the surface and determine the abundance of hydrogen in the shallow subsurface, and MARIE would characterize aspects of the near-space radiation environment to help gauge the radiation-related risk to human explorers. The Orbiter would also support communication with the '01 Lander. A decision was made in January 2000 to eliminate the Lander and Rover from this launch opportunity. However, as part of the re-planning efforts, some of the '01 Lander flight hardware is being considered for use on future missions. ...

Initiated under the President's Budget request last year, Mars Telecom Network and Science Micromissions will enhance the science return from Mars missions by utilizing micro-spacecraft launched as secondary payloads on commercial French Ariane-V geosynchronous transfer missions and potentially other launch vehicles. Mars Telecom Network is designed to support Mars global reconnaissance, surface exploration, sample return missions, robotic outposts, and eventual human exploration by: 1) Developing a communications capability to provide a substantial increase in data rates and connectivity from Mars to Earth; (2) Developing an in situ navigation capability to enable more precise targeting and location information on approach and at Mars. By developing the capability to provide increased data rates and connectivity, Mars Telecom Network also would enable greater information flow to the public for the purpose of engaging them in the Mars exploration adventure. In essence, Mars Network would be building a publicly accessible, live-video "gateway" to Mars that will enable researchers and the public to explore and experience Mars first-hand. Funding supports one Telecom Network Micromission to Mars in 2003 and at each subsequent 26-month opportunity, as well as a Mars aerostionary telecom orbiter to be launched in 2005 to provide a substantial increase in communications bandwidth and connectivity from Mars to Earth. In addition, funding will provide for Mars science micromissions which will be competitively selected under an open Announcement of Opportunity (AO) process with cost cap.

Funding in Future Missions provides for Mars missions in the 2003 and 2005 launch opportunities, and technologies required for these future Mars missions. The President's FY 2001 Budget provides additional funding in this line to support development and deployment of other potential sustained presence concepts at Mars that could enhance the science return and overall success of future missions.

2001 Mars Surveyor Orbiter and Lander, and beyond missions

Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity.

Critical Design Review Plan: 2nd Qtr., FY 1999 Actual: April 1999	Confirmation that the design is sufficient to move into full-scale development.
Orbiter & Lander ATLO Start Plan: 1st Qtr., FY 2000 Revised: TBD	Begin Assembly, Test and Launch Operations (ATLO) by integrating major components of the spacecraft into the spacecraft structure.
Orbiter & Lander Science Instruments Plan: 3rd Qtr., FY 2000 Revised: TBD	Deliver Mars 2001 Orbiter and Lander science instruments that meet capability requirements.
Ship Orbiter Plan: 1st Qtr., FY 2001 Revised: TBD	Ship to VAFB launch site.
Ship Lander Plan: 2nd Qtr., FY 2001 Revised: TBD	Ship to KSC launch site.
Orbiter Launch Plan: March FY 2001 Revised: TBD	Launch on schedule.
Lander Launch Plan: April FY 2001 Revised: TBD	Launch on schedule.
Future Mars Surveyor Missions Plan: FY 2000 Revised: TBD	Assuming the Mars Surveyor program architecture is confirmed, meet the milestones for the Mars '03 instrument selection and initiate implementation of the Lander mission. Deliver engineering models of the radio-frequency subsystem and antennae for the radar sounder instrument to ESA (if ESA approves the Mars Express mission), and select the contractors for the major system elements of the Mars Surveyor 05 mission.

ACCOMPLISHMENTS AND PLANS

MGS was launched in November 1996. The spacecraft arrived at its final mapping orbit in January 1999, and started its full mapping operations in March 1999.

The Mars Surveyor 98 mission, an orbiter and a lander, launched in December 1998 and in January 1999, respectively; however, both failed upon arrival at Mars.

The Mars Surveyor '01 spacecraft Critical Design Review took place in April 1999.

Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity. The detail of the revised schedules and outputs will be provided once the re-planning is completed.

BASIS OF FY 2001 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
HST operations	2,100	2,100	1,500
Other mission operations	115,200	73,300	78,500
Total	117,300	75,400	80,000

PROGRAM GOALS

The goal of the Mission Operations program is to maximize the scientific return from NASA's investment in spacecraft and other data collection sources. The Mission Operations effort is fundamental to achieving the goals of the Office of Space Science program because it funds the operations of the data collecting hardware that produces scientific discoveries. Funding supports satellite operations during the performance of the core missions, plus extended operations of selected spacecraft.

STRATEGY FOR ACHIEVING GOALS AND SCHEDULE & OUTPUTS

The Mission Operations program is working to dramatically reduce costs while preserving, to the greatest extent possible, science output. To do so, it will accept prudent risk, explore new conceptual approaches, streamline management and make other changes to enhance efficiency and effectiveness. The following is a comprehensive list of all Space Science spacecraft that are, or are expected to be, operational at any time between January 2000 and September 2001.

Hubble Space Telescope, HST (launched April 25, 1990; expected operations through ~2010)
HST science operations are carried out through an independent HST Science Institute, which operates under a long-term contract with NASA. Satellite operations, including telemetry, flight operations and initial science data transcription, are performed on-site at Goddard Space Flight Center under separate contract. While NASA retains operational responsibility for the observatory, the Science Institute plans, manages, and schedules the scientific operations.

International Solar-Terrestrial Physics, ISTP: Geotail (launched July 24, 1992; expected operations beyond FY 2001), Wind (launched November 1, 1994; expected operations beyond FY 2001), Polar (launched February 24, 1996; expected operations beyond FY 2001), Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995; expected operations beyond FY 2001)

Wind, Polar, SOHO, and Geotail are the core spacecraft of the ISTP program. Wind measures the energy, mass, and momentum that the solar wind delivers to the Earth's magnetosphere. Wind also carries a gamma ray instrument, the first Russian instrument

ever to be flown on a U.S. spacecraft. Polar provides dramatic images of the aurora and complementary measurements to provide a direct measure of the energy and mass deposited from the solar wind into the polar ionosphere and upper atmosphere. SOHO studies the solar interior by measuring the seismic activity on the surface; SOHO also investigates the hot outer atmosphere of the Sun that generates the variable solar wind, as well as UV and X-ray emissions affecting the Earth's upper atmosphere, the geospace environment, and the heliosphere. Geotail is a Japan-U.S. spacecraft that explored the deep geomagnetic tail in its first two years of flight and now is exploring the near-tail region on the night side and the magnetopause on the day side of the Earth.

Compton Gamma Ray Observatory, CGRO (launched April 5, 1991; expected operations until March 2000)
The CGRO's science objectives include studies of very energetic celestial phenomena: solar flares, cosmic gamma-ray bursts, pulsars, nova and supernova explosions, accreting black holes of stellar mass, quasar emissions, and interactions of cosmic rays with the interstellar medium. A gyroscope failed in early December 1999; the observatory is functioning with only two at this time. To help ensure accurate reentry, an initial decision has been made to conduct a controlled de-orbit maneuver in March 2000 while the observatory retains two functioning gyros. However, NASA is conducting studies to determine the feasibility of accurately de-orbiting the satellite with fewer than two gyros to maximize CGRO's research life, and the CGRO de-orbit decision will be re-examined one month prior to the scheduled de-orbit maneuver.

Chandra X-ray Observatory, CXO / Advanced X-ray Astrophysics Facility, AXAF (launched on July 23, 1999; expected operations through ~ FY 2009)
The objectives of Chandra are to: obtain high-resolution x-ray images and spectra in the 0.1-to-10-KeV wavelength range; investigate the existence of stellar black holes; study the contribution of hot gas to the mass of the universe; investigate the existence of dark matter in galaxies; study clusters and superclusters of galaxies; investigate the age and ultimate fate of the universe; study mechanisms by which particles are accelerated to high energies; confirm the validity of basic physical theory in neutron stars; and investigate details of stellar evolution and supernovae.

Relativity Mission, Gravity Probe-B, GP-B (launch scheduled September, 2001; expected operations beyond FY 2001)
The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. The theory has only been tested through astronomical observation and Earth-based experiments. The GP-B mission will explore more precisely the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect".

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics, TIMED (launch scheduled fall 2000; expected operations beyond FY 2001)
TIMED will explore the Earth's Mesosphere and Lower Thermosphere (60-180 kilometers), the least explored and understood region of our atmosphere.

Galileo (launched October 18, 1989; expected operations through January 2000)

Galileo is executing a series of close flybys of Jupiter and its moons, studying surface properties, gravity fields and magnetic fields, and characterizing the magnetospheric environment of Jupiter and the circulation of its Great Red Spot. In December 1997, the program began the Galileo Europa Mission (GEM), a detailed study of Jupiter's ice-covered moon running through 1999. Galileo will complete its extended-phase "Galileo Europa Mission" (GEM) in January 2000. At the present time NASA is examining science and cost options for a further extension through December 2000; this extension would enable unique science investigations in coordination with a Cassini fly-by of Jupiter, and would generate unique engineering data on the performance of spacecraft in high-radiation-dosage environments.

Cassini (launched October 15, 1997; expected operations through ~ 2008)
Cassini will conduct a detailed exploration of the Saturnian system including: 1) the study of Saturn's atmosphere, rings and magnetosphere; 2) remote and in-situ study of Saturn's largest moon, Titan; 3) the study of Saturn's other icy moons; and 4) a Jupiter fly-by to expand our knowledge of the Jovian System. During the transit from Jupiter to Saturn, Cassini will conduct unique radio-science measurements designed to detect ripples of gravitational field produced by catastrophic events in the galaxy. Cassini will arrive at Saturn in 2004. Proper trajectory is ensured through tracking and targeting maneuvers, and the health of science instruments is maintained by periodic checkouts.

Voyager Interstellar Mission (Voyager 1 launched September 5, 1977; Voyager 2 launched August 20, 1977; expected operations beyond FY 2001)
Voyager 1 and 2 are traveling beyond the planets, continuing to probe the outer heliosphere searching for the boundary between the solar system and the interstellar space.

Ulysses (launched October 6, 1990; expected operations beyond FY 2001)
Ulysses is approaching the south pole of the Sun and will transit the solar poles during 2001 during the peak of the current solar maximum period. The spacecraft is measuring the solar wind properties at high latitudes and is providing a unique 3-dimensional perspective of the heliosphere.

Rossi X-ray Timing Explorer, RXTE (launched December 30, 1995; expected operations beyond FY 2001)
RXTE uses three instruments to conduct timing studies of astronomical X-ray sources.

Advanced Composition Explorer, ACE (launched August 25, 1997; expected operations beyond FY 2001)
ACE is measuring the composition of the particles streaming from the Sun, as well as high-energy galactic cosmic rays.

Far Ultraviolet Spectroscopic Explorer, FUSE (launched June 24, 1999; expected operations beyond FY 2001)
FUSE will measure the amount of cold, warm, and hot plasma in objects ranging from planets to quasars. The objectives for the FUSE mission are to measure the abundance of deuterium produced by the Big Bang, the Milky Way, and distant galaxies; determine the origin and temperature of galactic gaseous clouds and observe interaction between solar wind and planetary atmospheres.

Solar Anomalous and Magnetospheric Particle Explorer, SAMPEX (launched July 3, 1992; expected operations beyond FY 2001)
SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

Fast Auroral Snapshot, FAST (launched August 21, 1996; expected operations beyond FY 2001)
FAST is a low-altitude polar orbit satellite designed to measure the electric fields and rapid particle accelerations that occur along magnetic field lines above auroras. Extremely high data rates (burst modes) are required to detect the presence and characteristics of the fundamental effects taking place.

Submillimeter Wave Astronomy Satellite, SWAS (launched December 5, 1998; expected operations through January 2001)
SWAS studies the chemical composition, energy balance and structure of interstellar clouds and the processes that lead to the formation of stars and planets.

Transition Region and Coronal Explorer, TRACE (launched April 1, 1998; expected operations beyond FY 2001)
TRACE observes, with high resolution, the effects of the emergence of magnetic flux from deep inside the Sun to the outer corona.

Wide Field Infrared Explorer, WIRE (launched March 4, 1999; expected operations as a testbed through FY 2000)
WIRE's primary mission ended when the on-board cryogen was exhausted soon after launch. It is being used as a testbed by other missions to test flight software and other capabilities. In between these engineering tests, some science observations to study astroseismology and the existence of extra-solar planets are performed.

Galaxy Evolution Explorer, GALEX (launch scheduled mid-CY 2001, expected operations beyond FY 2001)
GALEX will use an ultraviolet telescope during its two-year mission to explore the origin and evolution of galaxies and the origins of stars and heavy elements, and to detect millions of galaxies out to a distance of billions of light years. GALEX will also conduct an all-sky ultraviolet survey.

High Energy Solar Spectroscopic Imager, HESSI (launch scheduled July 2000, expected operations beyond FY 2001)
HESSI will observe the Sun to study particle acceleration and energy release in solar flares.

Microwave Anisotropy Probe, MAP (launch scheduled November 2000, expected operations beyond FY 2001)
The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos.

Imager for Magnetopause-to-Aurora Global Exploration, IMAGE (launch scheduled February 2000, expected operations beyond FY 2001)
IMAGE will study the global response of the Earth's magnetosphere to the changes in the solar wind.

Student Nitric Oxide Experiment, SNOE (launched February 25, 1998; operations expected through March 2000)

SNOE is a small scientific satellite investigating the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE was designed and built, and is being operated, entirely at the University of Colorado at Boulder.

High Energy Transient Explorer 2, HETE-2 (launch scheduled January 2000; operations expected beyond FY 2001)
The primary goal of HETE-2 is to determine the origin and nature of cosmic gamma-ray bursts.

Interplanetary Monitoring Platform-8, IMP-8 (launched October 26, 1973; expected operations beyond FY 2001)
IMP-8 performs near-continuous studies of the solar wind and the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

Extreme Ultraviolet Explorer, EUVE (launched June 7, 1992; expected operations through end of FY 2000)
EUVE is studying the sky at wavelengths once believed to be completely absorbed by the thin gas between the stars.

Mars Global Surveyor (launched November 7, 1996; expected operations beyond FY 2001)
MGS reached Mars in September 1997 and used aerobraking maneuvers to achieve its desired mapping orbit in March 1999, about one year later than planned due to unanticipated deflections in one of the solar array panels. During aerobreaking, MGS acquired high-resolution imagery of selected surface features, deleted remnants of a past field, acquired topographic data of both the north and south polar regions as well as selected regions of the northern hemisphere, and acquired surface compositional data of selected areas. In March 1999, MGS began its 2-year prime mapping mission, systematically acquiring data on surface features, atmospheric data, and mapping of magnetic properties. The MGS prime mission will be completed in February 2001.

Mars '01 Orbiter and Lander Operations. Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity. The detail of the revised schedules and outputs will be provided once the re-planning is completed.

Near Earth Asteroid Rendezvous, NEAR (launched February 17, 1996; expected operations through FY 2001)
NEAR flew by Earth for its final gravity assist in January 1998, and will arrive at its primary target (the asteroid 433 Eros) in February 2000. Originally scheduled for Eros rendezvous in February 1999, the start of prime science operations has been delayed by a premature cut-off during the first orbit insertion engine firing in December 1998.

Stardust (launched February 7, 1999; expected sample return to Earth in 2006)
Stardust will perform activities in support of the five-year cruise to rendezvous with Comet Wild-2.

Genesis (launch scheduled January 2001; expected operations beyond FY 2001)
The Genesis mission will collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis.

Deep Space 1, DS1 (launched October 24, 1998; expected operations beyond FY 2001)
The New Millennium Program focuses on testing high-risk, advanced technologies in space with low-cost flights. Though testing technologies is the primary goal of the flights, they also allow an opportunity to collect scientifically valuable data. Deep Space 1 has completed 100% of the testing required to validate the technologies, and the mission has been extended, with a new focus on gathering scientific information. Deep Space 1's mission took it by an asteroid on July 28, 1999. When DS1 flew by the asteroid Braille, it was an amazing 26 km away the body. The extended mission will include encounters with two comets.

NASA also participates in the following missions. The foreign partners provide for the operations costs of these missions, with NASA providing science contributions.

- **Astro-E (launch scheduled February 2000; expected operations beyond FY 2001)**
- **Cluster-II (launch scheduled June 2000 and July 2000; expected operations beyond FY 2001).**
- **X-ray Spectroscopy Mission, XMM (launched December 10, 1999; expected operations beyond FY 2001)**
- **Integral (launch scheduled September 2001; expected operations beyond FY 2001).**
- **Nozomi (launched July 3, 1998; expected operations beyond FY 2001)**
- **Advanced Spacecraft for Cosmology Astrophysics, ASCA (launched February 20, 1993; expected operations through FY 2001)**
- **Highly Advanced Laboratory for Communications and Astronomy, HALCA (launched February 12, 1997; expected operations FY 2001)**
- **Yohkoh (launched August 31, 1991; expected operations beyond FY 2001)**
- **Beppo-SAX (launched April 30, 1996; expected operations beyond FY 2001)**

ACCOMPLISHMENTS AND PLANS

Space Science continues to make progress in lowering mission operations costs while preserving the science return from operating missions. The program is utilizing the savings, and seeking additional cost reductions, in order to sustain operations of ongoing missions as long as is merited by the science return. The science community both inside and outside of NASA regularly reviews the mission operations program to ensure that only the missions with the highest science return are funded. In addition, we are launching smaller spacecraft, and engaging in more international collaborations. As a result, NASA expects to be able to support an increasing number of operational spacecraft through FY 2001 despite a smaller MO budget. In total, at the end of FY 2001, we will have approximately 27 operational Space Science spacecraft, in addition to participation in the operations of 12 foreign spacecraft. This compares to 18 at the beginning of FY 1995. As of the end of January 2000, we have 26 operational missions (29 spacecraft), in addition to participation in the operations of 7 foreign spacecraft.

Missions expected to begin operations before the end of FY 2001 include HETE-II (06/00), Astro-E (2/00), IMAGE (02/00), Cluster-II (06/00), HESSI (07/00), GP-B (9/01), TIMED (fall/00), MAP (11/00), Genesis (01/01), 2001 Mars Chemical Mapper (03/01), Catsat (07/01), Integral (09/01), and GALEX (09/01).

BASIS OF FY 2001 FUNDING REQUIREMENT

SUPPORTING RESEARCH AND TECHNOLOGY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Supporting Research and Technology	916,100	1,179,285	1,302,800
Technology Program	470,200	613,197	740,300
Core Program	211,500	254,496	272,000
Space Science Technology	59,200	92,000	97,100
Cross-Enterprise Technology	152,300	162,496	174,900
Focused Programs	226,600	342,901	424,500
Astronomical Search for Origins	94,700	131,201	133,200
[Construction of Facilities (non-add)]	[2,500]	[2,500]	
Advanced Deep Space Systems	97,100	162,200	181,800
Sun-Earth Connections	20,200	26,600	78,000
Structure & Evolution of the Universe	14,600	22,900	31,500
Flight Validation	32,100	15,800	43,800
Research Program	403,100	529,188	523,600
Research and Analysis	192,200	237,588	211,600
Data Analysis	210,900	291,600	312,000
Suborbital	42,800	36,900	38,900
Balloon Program	13,500	13,300	15,300
Sounding Rockets	29,300	23,600	23,600

PROGRAM GOALS

OVERALL SUPPORTING RESEARCH AND TECHNOLOGY

The Space Science Enterprise's Supporting Research and Technology program is comprised of three major components: the Technology program, the Space Science Research program (consisting of Research and Analysis and Data Analysis) and the Suborbital program. These three elements focus on the activities that occur both before and after space flight mission development and operations. The proper levels of investment in technology, research and suborbital programs are essential to obtaining the high-value scientific results that will enable the Space Science Enterprise to fulfill its mission: to solve the mysteries of the universe including its origins and destiny, explore the solar system, discover planets around other stars, and search for life beyond Earth.

TECHNOLOGY PROGRAM

The goals of the Technology Program are to: (1) lower mission life-cycle costs; (2) develop innovative technologies to enable new kinds of missions; (3) develop and nurture an effective science-technology partnership; (4) stimulate cooperation among industry, academia, and government; and (5) identify and fund the development of important cross-Enterprise technologies.

SPACE SCIENCE RESEARCH PROGRAM

The goals of the Space Science Research and Analysis Program are: (1) to enhance the value of current space missions by carrying out supporting ground-based observations and laboratory experiments; (2) to conduct the basic research necessary to understand observed phenomena, and develop theories to explain observed phenomena and predict new ones; and, (3) to continue the analysis and evaluation of data from laboratories, airborne observatories, balloons, rocket experiments and spacecraft data archives. In addition to supporting basic and experimental astrophysics, space physics, and solar system exploration research for future flight missions, the program also develops and promotes scientific and technological expertise in the U.S. scientific community.

The goal of the Space Science Data Analysis program is to maximize the scientific return from our space missions, within available funding. The Data Analysis program is the source of the enormous scientific return generated from our investments in space hardware. Besides scientific advancements, the Data Analysis program also contributes to public education and understanding through media attention and our own education and outreach activities.

The principal goal of the Suborbital program is to provide frequent, low-cost flight opportunities for space science researchers. The program allows these scientists to fly payloads to conduct research on the Earth's ionosphere and magnetosphere, space plasma physics, astronomy, and high-energy astrophysics. The program also serves as a technology testbed for instruments that may ultimately fly on orbital spacecraft, thus reducing cost and technical risks associated with the development of future space science missions. It is also the primary opportunity for training graduate students and young scientists in hands-on space flight research techniques.

STRATEGY FOR ACHIEVING GOALS

TECHNOLOGY

The Space Science Enterprise's Technology Program consists of three major elements: core programs, focused programs, and flight validation. These elements are designed to develop technologies from the conceptual stage to the point where they are ready to be incorporated in the full-scale development of science mission spacecraft.

Core Programs are comprised of two major components: Space Science Technology and Cross-Enterprise Technology.

Space Science Technology provides for several activities that cover a broad range of baseline technological capabilities supporting multiple applications. Most of the funding in this area provides for computation and information technologies. One new element of this program is the Intelligent Systems initiative that focuses on exploiting revolutionary advances in information technology to meet the needs of NASA's missions in the 21st century. Other core capabilities, such as the development of new science instruments, ground system hardware and software for deep space missions, and other elements are also included in this area. The elements of the Space Science Technology Program are described below:

- Explorer Program Technology develops leading-edge technologies to enable partnerships in relatively small technology projects with industry, academia, NASA Field Centers, and other government agencies. These technologies must show application across multiple systems or missions, with an emphasis on meeting Explorer Program technology needs for improved spacecraft and instrument systems, and must also lead to lower mission costs.

- Information Systems provides technology for multidisciplinary science support in the areas of data management and archiving, networking, scientific computing, visualization, and applied information systems research and technology.

- The NASA HPCC Program will accelerate the development, application, and transfer of high-performance computing technologies to meet the science and engineering needs of the U.S. science community and the U.S. aeronautics community. Within this program the Space Science Enterprise funds the Remote Exploration and Experimentation (REE) component, which will develop low-power, fault-tolerant, high-performance, scaleable computing technology for a new generation of microspacecraft.

- Science Instrument Development funds initial technology work on new types of detectors and other scientific instruments. Many of these new instrument concepts are tested and flown aboard sounding rockets or balloons, and may later be adapted for flight aboard future free-flying spacecraft.

- The Planetary Flight Support (PFS) program provides ground system hardware, software, and mission support for all deep space missions. Planetary Flight Support activities are associated with the design and development of multi-mission ground operation systems for deep space and high-Earth-orbiting spacecraft. PFS also supports the development of generic multi-mission ground system upgrades such as the Advanced Multi-Mission Operations System (AMMOS). This new capability is designed to significantly improve our ability to monitor spacecraft systems, resulting in reduced workforce levels and increased operations efficiencies for Cassini and future planetary missions. New missions in the Discovery and Mars Surveyor programs will work closely with the Planetary Flight Support Office to design ground systems developed at minimum cost, in reduced time, with greater capabilities, and able to operate at reduced overall mission operations costs.

- Other Space Science Core Technology provides funding to those technologies that are applicable to multiple science themes within OSS. Technologies eventually move from this category into a focused program (described below) when they have successfully been demonstrated and are ready for infusion into a focused program mission.

- Through the Information Technology Initiative, the President's FY 2001 Budget provides additional funds for the Intelligent Systems Program, which will provide NASA with autonomous and semi-autonomous computational capabilities to enable future missions in deep space, planetary exploration, aerospace applications, and Earth observing systems and data understanding. Self-sustaining networks of robotic explorers in future NASA missions will require intelligent systems technologies far more advanced than current Government or commercial capabilities and are the priority application for the Intelligent Systems Program. Many future missions in all NASA Enterprises will require autonomous robotic systems capable of cooperative behaviors, near-real-time learning, self-healing/self-diagnosis, and on-board decision making. These future NASA-wide mission requirements have led to the identification of four critical areas for Intelligent Systems.
    - Automated Reasoning to enable networks of robotic explorers and other NASA missions to build and use systems that reliably make decisions with limited human intervention. The degree of autonomy required is far beyond that achievable today.
    - Human-Centered Computing to enable NASA's missions by radically enhancing both individual and team productivity through the inclusion of computer-based agents. As computer-based agents become more capable, and are designed to exercise more autonomy, there is less need to distinguish between computer-based and human agents except with regard to their unique skills.
    - Intelligent Data Understanding to enable robots, spacecraft and earth observing satellites to spot interesting trends in raw data and transform raw data into higher-level knowledge. Transforming data into knowledge will enable independent robotic investigation and discovery, and will greatly reduce communications bandwidth requirements.
    - Revolutionary Computing to enable advanced spaceborne computing by improving the capabilities of space-ratable processors by two or three orders of magnitude, embracing radically new approaches to computing that are risky but promise substantial payoffs.

  The execution strategy of the Intelligent Systems Program emphasizes:
  1. Performance by teams of experts from the intramural and extramural communities;
  2. Research quality ensured through continuous review by an eminent External Advisory Council of computer scientists;
  3. Strategic focus maintained by a Mission Needs Council of senior NASA personnel with mission responsibilities.

  The Intelligent Systems Program will allocate approximately 50% of its funds for competition. In order to assure the highest benefit to NASA of extramural participation, however, particular emphasis will be given to research partnerships between NASA and universities/companies that involve some on-site activity at NASA Centers. The goals of the Program are extremely ambitious, and they will be realized only by the highest quality research. To that end, every part of the Program will be reviewed regularly by an eminent board of computer scientists. This External Advisory Council will be constituted of nationally recognized experts in the four focus areas of the program, drawn from key parts of the academic, public and private sectors. The Program will also be regularly reviewed by a Mission Needs Council, made up of senior NASA officials with oversight of relevant mission arcas. This group will assure program focus on critical future NASA mission requirements.

The Cross-Enterprise Technology program supports the cross-cutting technology requirements for all NASA Space Enterprises. The technologies are generally multi-mission in nature and this work tends to focus on the earlier stages of the technology life-cycle.

The technologies developed under the Cross-Enterprise program form the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions.

A new feature of the Cross-Enterprise Technology program is the use of NASA Research Announcements (NRAs) to broadly announce and compete an increasingly larger portion of the program. This will open up opportunities to a wider community of technology developers and will ensure the excellence of the program through peer-reviewed competition. The implementation of the NRA process in Cross-Enterprise Technology began in FY 1999.

A second change implemented in FY 1999 was the change in Cross-Enterprise Technology program structure. The new program structure is based on integrated, systems-level "thrust areas", which are more clearly aligned with multi-Enterprise requirements and reflect the way the technology development work is managed. The thrust areas are as follows:

- Advanced Power and On-Board Propulsion: Subsystems and components that handle power generation, energy storage, and in-space propulsion to enable crewed and robotic spacecraft to travel faster and deeper into space, with longer mission duration.

- Sensors and Instrument Components: Breakthrough technologies for a wide range of remote sensing and observational capabilities for use in Space Science and Earth Science applications.

- Distributed Spacecraft: Precision-formation-flying technologies, spacecraft constellations, and fleet control technologies.

- High Rate Data Delivery: Technologies to more efficiently collect, transmit, receive, store and access data from operational missions.

- Micro/Nano Spacecraft: Technologies to enable smaller, lower mass spacecraft with greater functionality. This area will also develop technologies to integrate developments from other thrust areas, such as miniature power, propulsion, instruments, and other components, into functioning miniature spacecraft.

- Surface Systems: Technologies for spacecraft to operate and explore on the surface, below the surface, or in the atmospheres of planetary and other celestial bodies.

- Thinking Space Systems: Development of thinking, inquisitive, self-commanding systems that can recognize objects or phenomena of scientific interest and then conduct observations accordingly.

- Ultralight Structures and Space Observatories: Technologies enabling the deployment of large, lightweight space structures. These include precision deployment capabilities, membrane and inflatable structures, and high performance materials.

- Next Generation Infrastructure: Development of technologies to vastly improve the ability to conceive, design, test, and operate future space systems.

Beginning in FY 2000, additional funding for the Cross-Enterprise Technology program budget was provided to support two new initiatives: Gossamer Spacecraft and Next Decade Planning.

The Gossamer Spacecraft initiative supports the ultralight structures and space observatories thrust area to develop and demonstrate the deployment, control, and utility of thin-film deployable structures. Technologies developed in this area could support several future applications: solar sail propulsion, large aperture astronomical observatories, large aperture remote sensing, large-scale power collection and transmission in space, and interstellar precursor missions.

Next Decade Planning is supporting improved cross-agency planning with the objective of improving technology selection through the ongoing development and refinement of a robust set of potential civil space programs that could be undertaken in the next decade.

The President's FY 2001 Budget includes an augmentation to the Space Science budget for Nanotechnology ($5 million). NASA will participate in the National Nanotechnology Initiative by pursuing fundamental investigations in quantum effects, atom imaging and manipulation, nanotube research, and other related areas. These investigations are expected to lead to applications such as: lighter, smaller, and more capable spacecraft; biomedical sensors and medical devices; powerful, small, low-power computers; radiation-hard electronics; thin-film materials.

In addition, the Cross-Enterprise Technology program includes the Space Solar Power project, which is developing goals and objectives, detailed roadmaps, and technology investment priorities through ongoing system studies and initial technology activities.

Focused Programs are dedicated to high-priority technologies needed for specific science missions. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. Technology activities can encompass developments from basic research all the way to infusion into science missions. Focused Programs also includes mission studies -- the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions through detailed analysis of the trade-offs between design considerations and cost. In order to ensure that the decisions resulting from mission studies are realistic and can be implemented, the studies will employ new techniques for integrated design and rapid prototyping.

The FY 2001 budget estimate includes four categories of activities under focused programs. These categories correspond to the four scientific themes of the Space Science Enterprise: Astronomical Search for Origins, Advanced Deep Space Systems Development (Solar System Exploration), Sun-Earth Connections, and Structure and Evolution of the Universe. These elements are described below:

- Astronomical Search for Origins Technology develops critical technologies for studies of the early universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, vibration isolation and structural

quieting systems, optical delay lines and large lightweight optics. Missions supported in this area include the Space Interferometry Mission (SIM), Next Generation Space Telescope (NGST), the Space Technology 3 mission and Terrestrial Planet Finder (TPF), as well as the provision of interferometry capability to the ground-based Keck telescopes. This line also funds construction of the Optical Interferometry Development Laboratory at the Jet Propulsion Laboratory in FY 1999 and FY 2000.

- Advanced Deep Space Systems Technology provides for the development, integration, and testing of revolutionary technologies for solar system exploration. Emphasis is on micro-avionics, autonomy, computing technologies, and advanced power systems. Funding is included in this line for the Center for Integrated Space Microsystems (CISM) and the Advanced Power System project. Funding in this area supports a Europa orbiter and a Pluto/Kuiper Express mission. Technology developed in this area also supports Solar Probe (a Sun-Earth Connections mission), which shares a significant amount of common technology with Europa Orbiter and Pluto/Kuiper Express. The President's FY 2001 Budget provides additional funding in the outyears in Advanced Deep Space Systems to support a sustained presence at potential high priority research targets in the solar system.

- Sun-Earth Connections (SEC) Technology develops the technologies necessary for missions focused on observing the Sun and the effects of solar phenomena on the space environment and on the Earth. Technology funded in this area supports missions now under study such as STEREO, Solar-B, and Solar Probe, as well as future SEC missions.

  The President's FY 2001 Budget includes an augmentation for the Living With a Star Initiative ($20 million in FY 2001). Living With a Star is a set of missions and enhancements to current programs designed to study solar variability and its effects on humanity. This initiative will fundamentally change the emphasis of the Sun-Earth Connections theme by having dual objectives, one studying solar-terrestrial physics to understand basic natural processes (current program) and the other stressing investigations into how solar variability affects humans and technology. Understanding the Sun is of supreme importance because we have increased dependence on space-based systems and soon will have a permanent presence of humans in Earth orbit. Solar variability can affect: civilian and military space systems; national defense; human space flight; electric power grids; GPS signals; high-frequency radio communications; long-range radar; microelectronics and humans in high-altitude aircraft; and terrestrial climate. Prudence demands that we fully understand the solar effects on these systems. In addition, given the massive economic impact of even small changes in climate, we should fully understand both natural and anthropogenic causes of global climate change. The Living With a Star Initiative capitalizes and expands upon investments being made in the Solar Terrestrial Probes program in missions such as TIMED, STEREO, and Solar-B, as well as the ST-5 microsat technology demonstration mission in the Flight Validation Program. LWS will also pursue partnerships with other federal agencies.

- Structure and Evolution of the Universe Technology provides for the development of technologies to study the large-scale structure of the universe, including the Milky Way and objects of extreme physical conditions. SEU missions are aimed at explaining the cycles of matter and energy in the evolving universe, examining the ultimate limits of gravity and energy in the universe and forecasting our cosmic destiny. Technology funded in this area supports missions now under study, such as FIRST and GLAST, as well as future SEU missions, particularly Constellation-X.

The table below shows the currently planned missions for each of the focused programs, and indicates the planned start of implementation and the funding (in thousands of dollars) for each mission.

Focused Program Missions	Implementation Start	FY 1999	FY 2000	FY 2001
Origins				
SIM	FY 2002	34,165	40,450	48,000
NGST	FY 2004	32,190	46,560	61,540
TPF	FY 2008	1,600	4,000	10,000
ST3	FY 2002	9,200	8,000	17,000
Keck Interferometer	FY 1998	16,400	13,700	6,400
Deep Space Systems				
Europa Orbiter	FY 2000	15,400	57,300	93,000
Pluto/Kuiper Express	FY 2000	700	7,000	19,600
Structure & Evolution of the Universe				
FIRST	FY 2001	6,635	16,110	20,800
GLAST	FY 2002	4,850	4,850	8,730
Sun-Earth Connections				
Solar-B	FY 2000	5,000	9,600	19,500
STEREO	FY 2001	7,000	8,300	23,600
Solar Probe	FY 2003	400	3,200	7,400

The **Flight Validation Program** (previously referred to as the New Millennium Program) provides a path to flight-validate key emerging technologies to enable exciting science missions. Through the Flight Validation program, high-value technologies are made available for use in the Space Science program without imposing undue cost and risk on individual science missions. This program has been restored in this budget, but has also been restructured to increase its levels of openness and competitiveness, to reduce the size and cost of the missions, and to ensure focus on technology demonstration, versus science data gathering. The program will include validation of both complete systems and subsystems. At planned funding levels through 2005, it is anticipated that two small ($40-50 million each) and one medium ($100-150 million) system validations will be enabled every four years, along with two-to-three subsystem validations per year, including carrier and secondary launch. Partnerships with industry, universities, and other government agencies will continue to be pursued, where feasible, to maximize both the return on investment in technology development and rapid infusion.

RESEARCH

The Space Science Research and Analysis Program carries out its goals and objectives by providing grants to universities and nonprofit and industrial research institutions, as well as by funding scientists at NASA Field Centers and other government agencies. Approximately 1,500 grants are awarded each year after a rigorous peer review process; only about one out of four proposals is accepted for funding, making this research program among the most competitive in government. This scientific research is the foundation of the Space Science Enterprise. Key research activities include the analysis and interpretation of results from current and past missions; synthesis of these analyses with related airborne, suborbital, and ground-based observations; and the development of theory, which yields the scientific questions to motivate subsequent missions. The publication and dissemination of the results of new missions to scientists and the world is another key element of the Research and Analysis Program strategy, since it both inspires and enables cutting-edge research into the fundamental questions that form the core of the mission of the Space Science Enterprise. With the exception of a proprietary period of up to one year for some missions, 100% percent of the data from current and past Space Science missions is openly available to the public via the internet. (These proprietary periods are being phased out.)

The OSS NRA for Research Opportunities in Space Science (ROSS) solicits proposals for basic investigations to seek to understand natural space phenomena across the full range of space science programs relevant to the four OSS science themes. Participation in this program is open to all categories of U.S. and non-U.S. organizations including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Minority and disadvantaged institutions are particularly encouraged to apply. Recommendations for funding are based on the independent evaluation of each proposal's science and technical merits, and its relevance to the OSS objectives as described in the NRA.

The Space Science Data Analysis program supports scientific teams using data from our spacecraft. Depending on the mission, scientists supported may include Principal Investigators who have built scientific instruments and are guaranteed the data from those instruments, Guest Observers who have successfully competed for observing time, and researchers using archived data from current or past missions. Data Analysis funding also supports a number of critical "Science Center" functions that are necessary to the operation of the spacecraft but do not involve the actual commanding of the spacecraft. For instance, the planning and scheduling of spacecraft observations, the distribution of data to investigators, and data archiving services are all supported under Data Analysis.

SUBORBITAL

The Suborbital program provides the science community with a variety of options for the acquisition of in-situ or remote sensing data. Aircraft, balloons and sounding rockets provide access to the upper limits of the Earth's atmosphere. Activities are conducted on both a national and international cooperative basis.

Balloons provide a cost-effective way to test flight instrumentation in the space radiation environment and to make observations at altitudes above most of the water vapor in the atmosphere. In many instances, it is necessary to fly primary scientific experiments on balloons, due to size, weight, cost considerations or lack of other opportunities. Balloon experiments are particularly useful for

infrared, gamma-ray, and cosmic-ray astronomy. In addition to the level-of-effort science observations, the program has successfully developed balloons capable of lifting payloads greater than 5000 pounds. Balloons are now also capable of conducting a limited number of missions lasting 9 to 24 days, and successful long-duration flights are being conducted in or near both polar regions. The Balloon contract is managed by the GSFC Wallops Flight Facility (WFF). Flight operations are conducted by the National Scientific Balloon Facility (NSBF), a government-owned, contractor-operated facility in Palestine, Texas.

Analytical tools have been developed to predict balloon performance and flight conditions. These tools are being employed to analyze new balloon materials in order to develop an ultra-long-duration balloon (ULDB) flight capability (approximately 100 days), based on super-pressure balloons. An integrated management team has been established to develop and test the balloon vehicle and balloon-craft support system.

Sounding rockets are uniquely suited to perform low-altitude measurements (between balloon and spacecraft altitude) and to measure vertical variations of many atmospheric parameters. Sounding rockets are used to support special areas of study, such as: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including aurora production and energy coupling into the atmosphere; and the nature, characteristics and spectra of radiation of the Sun, stars and other celestial objects. In addition, sounding rockets allow several science disciplines to flight test instruments and experiments being developed for future space missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Launch operations are conducted from facilities at WFF, Virginia; White Sands, New Mexico; and Poker Flat, Alaska, as well as occasional foreign locations. A performance-based contract was awarded February 1999 to allow the government to transition away from operational control. The contract is managed by the GSFC/WFF.

In an effort to broaden the education opportunities using experiments built by students and flown on sounding rockets and stratospheric balloons, a Student Launch Program has been established for U.S. institutions of higher learning. This provides students, for the bachelor's through master's degrees, an opportunity to work on a reasonably complex project from its inception to its end, in a timeframe tenable within their academic careers. NASA expects to continue its competitive selection of this program with release of a new research announcement in FY 2000.

SCHEDULE & OUTPUTS

Technology Program

Space Science Core Technology

First-Generation computing testbed Plan: 2nd Qtr FY 1999 Revised: 3rd Qtr FY 2000	For HPCC Remote Exploration and Experimentation (REE) program, install first-generation scaleable embedded computing testbed operating at 30-200 MOPS/watt. Difficulties with the hardware design have delayed delivery.

Demonstrate scaleable computer for spaceborne applications Plan: 3rd Qtr. FY 1999 Revised: 4th Qtr. FY 2000	For HPCC Remote Exploration and Experimentation (REE) program, demonstrate scaleable spaceborne applications on first-generation embedded computing testbed. All of the applications have been delivered and demonstrated on a commercial parallel computer and are awaiting delivery of the testbed.
HPCC Plan: FY 2001	Demonstrate a real time capability with software implemented fault tolerance for embedded scalable computers. Real time performance latencies of less than 20 milliseconds are to be sustained at fault rates characteristic of deep space and low Earth orbit (LEO).
Information Systems Plan: FY 2000	Information Systems R&T will demonstrate the search, discovery, and fusion of multiple data products at a major science meeting.
Information Systems Plan: FY 2000	Information Systems R&T will accomplish and document the infusion of five information systems R&T efforts into flight projects for the broad research community.
Information Systems Plan: FY 2001	Information Systems R&T will demonstrate Virtual Observatory capability from investigator workstation for multi-wavelength discovery, analysis, and visualization across collective set of space and ground astronomical surveys; demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of Mars '03 and '05 missions.
Information Systems Plan: FY 2001	Information Systems R&T will demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of Mars '03 and '05 missions.
Explorer Program Technology Plan: FY 2001	Complete 45 Explorers Technology Investigations selected in FY99.
Explorer Program Technology Plan: FY 2001	Implement awards for additional investigations planned for selection in FY00.
Intelligent Systems Program Management Plan: FY 2000	The Program will establish the program investment portfolio and organiz the Program office and management structure.
Intelligent Systems Initial Procurement Plan: FY 2000	Initial IS research procurement targeted toward attracting academic and industry collaborators with NASA.

Intelligent Systems NAR Plan: FY 2000	A Non-Advocate Review will be held.
Intelligent Systems Plan: 1st Qtr FY 2001	Develop an initial set of organization-wide knowledge management strategies based on Operations Center-identified priorities and opportunities.
Intelligent Systems External Assessment Plan: 4th Qtr FY 2001	Program Assessment reviewed by External Advisory Council & Mission Needs Council.
Intelligent Systems Awards Plan: FY 2001	Awards will be concomitant with the beginning of the 2001 program year. A second research opportunity cycle will begin in late 2001, targeted toward a second set of awards in mid-2002.
Intelligent Systems Architectures Plan: 3rd Qtr FY 2001	Develop an initial set of promising revolutionary computing architectures for relevant space applications.
Intelligent Systems Data Understanding Methodologies Plan: 4th Qtr FY 2001	Structure Earth Science and Vehicle maintenance data sets for use by the developers of advanced Data Understanding methodologies, and perform initial tests of such methodologies.
Intelligent Systems Automated Reasoning Plan: 4th qtr FY 2001	Integrate automated reasoning and other software components with the objective of designing and specifying a modular autonomy architecture for robotic networks.

Cross-Enterprise Technology

Conduct on-orbit Ranger telerobotic flight experiment Plan: 4th Qtr. FY 99 Revised: Under review	This experiment will demonstrate multiple on-orbit robotic servicing capabilities relevant to science payload servicing and Space Station assembly and maintenance. The original target launch date of FY 2000 has been postponed due to STS manifesting considerations. A FY 2001 launch opportunity is currently being pursued.
Develop Wide-Band Low-Power Electronically-Tuned Local Oscillator Sources up to 1.3 THz Plan: 3rd Qtr., FY 1998 Revised: 3rd Qtr., FY 2000	A wide-band local oscillator (with 15% bandwidth) has been demonstrated operating at frequencies up to 0.5 THz. Construction of components operating at higher frequencies is underway. Lab demonstration of local oscillators operating at frequencies up to 1.9THz is planned for 3Q00. Technology approach and development schedule changed to reflect new advances in amplifier technology.

NRA Release Plan: 2nd Qtr., FY 1999 Actual: 1st Qtr., FY 1999	Release NASA Research Announcement (NRA) for Cross-Enterprise technology development. NRA was combined with the Explorer Technology NRA.
Task Selections Plan: 4th Qtr., FY 1999 Actual: 3rd Qtr., FY 1999	Select tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development following competitive review. NRA was combined with the Explorer Technology NRA, and awards were made 3rd Qtr., FY 1999.
Task Selections Plan: 4th Qtr., FY 2000	Select first set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.
Task Selections Plan: FY 2001	Select second set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.
Full and Open Competition Plan: End of FY 2000	One hundred percent of tasks subjected to full and open competition and/or external non-advocate review by end of FY 2000.
Gossamer Spacecraft NRA Release Plan: 2nd Qtr., FY 2000	Release first annual Gossamer Spacecraft NRA seeking proposals for technical concepts and predevelopment activities.
Gossamer Spacecraft NRA Selections Plan: 4th Qtr., FY 2000	Make initial awards in response to proposals for Gossamer Spacecraft technical concepts and predevelopment activities.

Focused Programs

Origins

ST-3 System Arch. Review Plan: August 1999 Revised: October 2000	System Architecture & Requirements Review. Delay due to significant program rephasing and replanning to bring ST-3 and TPF schedules into alignment, resulting in extended Phase B for ST-3.
ST-3 Technology Development Plan: FY 2001	Successfully complete PDR as well as project and spacecraft CDR.

Space Interferometry Mission (SIM) Non-Advocate Review Plan: 2nd-4th Qtr. FY 1999 Revised: 1st Qtr., FY 2002	Conduct the preliminary non-advocate review of the high precision astrometry and synthetic aperture imaging technologies for space-based interferometers. Key features include optical collectors on a 10-meter baseline and 10-milli-arcsecond synthesized imaging. Due to additional technology development needed to retire risk before entering Phase C/D, SIM launch date has been delayed to FY 2006. As a result, the NAR is now scheduled for the 1st quarter of FY 2002.
SIM Testbed Demonstration Plan: May 2000	Demonstrate, in May 2000, that an rms optical path difference can be controlled at 1.5 nanometers, operating in an emulated on-orbit mode.
SIM SRR Plan: FY 2001	Complete System Requirements Review (SRR) and initiate Phase B.
SIM Nulling Demonstration Plan: FY 2001	Demonstrate stabilization for nulling to one nanometer. Nulling is required to remove starlight that would wash out SIM's view of planets in other solar systems.
Keck Fringe Detection Plan: FY 2000	Development of the interferometer program for connecting the twin Keck 10-meter telescopes with an array of four two-meter class outrigger telescopes will be tested by detecting and tracking fringes with two test siderostats at two- and ten-micron wavelengths.
Keck Technology Development Plan: FY 2001	Combine 2 Keck telescopes; install first outrigger telescope.
NGST Technology Testbed Development Plan: FY 2000	Complete the NGST Developmental Cryogenic Active Telescope Testbed (DCATT) phase 1, measure ambient operation with off-the-shelf components, and make final preparations for phase 2, the measurement of cold telescope operation with selected "flight-like" component upgrades.
NGST Inflatable Sun Shield Development Plan: FY 2001	Inflatable Shield in Space (ISIS) ready to fly on Shuttle; release AO for Science Instrument; down-select to a single phase 2 prime contractor.
NGST Science Instrument AO Plan: FY 2001	Release AO for NGST Science Instruments.
NGST Phase 2 Down-Select Plan: FY 2001	Down-select to a single phase 2 prime contractor.

TPF Technology Development Plan: FY 2000	Complete and deliver a technology development plan for the Terrestrial Planet Finder (TPF) mission. This infrared interferometer requires the definition of technologies that will not be developed or demonstrated by precursor missions.
TPF Architectural Definition Plan: FY 2001	Award architectural definition contracts.
TPF Phase 2 Industrial Contracts Plan: FY 2001	Develop RFP for second phase of industrial contracts.
TPF Starlight Nulling Plan: FY 2001	Test starlight nulling breadboard.

Deep Space System (DSS) -

CISM Curriculum Plan: 4th Qtr. FY 1998 Actual: 4th Qtr. FY 1999	Develop university curriculum for two CISM technology thrust efforts: Systems on a Chip, and Revolutionary Computing Technologies. Curriculum for Systems on a Chip completed in July 1998, and implemented at the University of Illinois-Chicago. Curriculum for Revolutionary Computing Technologies completed in FY 1999, and has been implemented at Notre Dame University.
CISM Technology Development Plan: 3rd Qtr FY 2000 Actual: FY 1999	The 1st generation system on a chip prototype was fabricated earlier this year at MIT Lincoln Labs and has been delivered to JPL ahead of schedule. It will begin performance testing during FY 2000.
CISM Technology Development Plan: 3rd Qtr., FY 2000	Deliver first engineering model of an integrated avionics system.
CISM Technology Development Plan: FY 2001	Demonstrate and deliver prototype advanced power transistor [0.35 micron SOI (Silicon On Insulator) CMOS (Complementary Metallic Oxide Semiconductor)].
CISM Active Pixel Sensor Plan: FY 2001	Demonstrate Active Pixel Sensor with advanced processing capabilities on a single chip.
X-2000 Testbed design Plan: 4th Qtr FY 1999 Actual: 4th Qtr FY 1999	First delivery of an integrated and tested spacecraft avionics testbed design. The X2000 testbed design has been completed and is being prepared for operational use.

X-2000 Technology Development Plan: FY 2000	The first engineering model (EM-1) of the X2000 First Delivery will be delivered. Successful development includes the integration of all EM-1 hardware, the functional verification of delivered hardware and software, and the ability to support ongoing testing, hardware integration, and software verification for delivered software.
X-2000 Technology Development Plan: FY 2001	Deliver engineering model and flight set of avionics.
Solar System Exploration (non-Mars) First Mission C/D Start Plan: FY 2000 Revised: 1st Qtr., FY 2001	Successfully complete a preliminary design for either the Europa Orbiter or Pluto-Kuiper Express mission (whichever is planned for earlier launch) that is shown to be capable of achieving the Category 1A science objectives with adequate cost, mass, power, and other engineering margins. Preliminary Design Reviews (PDRs) delayed due to problems experienced with Advanced RTG, a major technology feeder.
Europa Orbiter Avionics Engineering Model I&T Plan: July 2000	Begin integration and test of the Avionics Engineering Model.
Future Deep Space Systems Planning Plan: FY 2001	Deliver X-2003 Level 1-3 Requirements Documents, define subsystem, complete definition of system architecture.
Future Deep Space Multi-Functional Structures Plan: FY 2001	Demonstrate intermediate-level multi-functional structures (MFS).
ARPS Plan: FY 2000 Actual: N/A	Fabricate and test 15 prototype AMTEC cells and complete the final design of Alkali Metal Thermo-Electric Converter (AMTEC) cells (3/00). Complete the final design for a 75-watt ARPS (4/00). Begin the prototype AMTEC 4-cell lifetime test and begin qualification unit fabrication (9/00). Project terminated during FY 1999 due to insufficient technical progress. Alternative advanced power program being formulated.
DS-4 Critical Design Review Plan: September 2000 Actual: N/A	Complete the system CDR for the New Millennium Deep Space-4 (Champollion) project before the end of FY00, including successful completion of the avionics subsystem CDR and the mechanical subsystem CDR. The ST-4/Champollion project was cancelled on July 1, 1999 to address other Space Science high-priority requirements.

SEC

Complete Phase A and Transition to Detailed Design for Solar-B Instruments Plan: 4th Qtr. FY 1999 Actual: October 1999	Complete concept development for focal plane instrumentation for the optical telescope and X-ray telescope. Phase B effort started November 1999.
Deliver Solar-B Electrical Engineering Models Plan: September 2000	Complete and deliver for testing Solar-B's four Electrical Engineering Models.
Deliver Solar-B Telescope Engineering Model Plan: FY 2001	Deliver engineering model of the optical telescope and x-ray telescope.
STEREO Technology Development Plan: FY 2000	Complete STEREO Phase A studies by June 2000, including the release of an AO for investigations with specific instruments and selection of the formulation phase payload.
STEREO Technology Development Plan: FY 2001	Successfully complete Phase B effort, including Confirmation Review.
Solar Probe Technology Development Plan: FY 2001	Begin Solar Probe prototype thermal shield fabrication.
Complete Living With a Star Strategic Plan Plan: March FY 2001	Complete Living With a Star Project Strategic Plan for the OSS Strategic Plan.
Future ST Probes Technology Development Plan: FY 2001	Complete preliminary concept definitions for spacecraft systems and instruments for Magnetospheric Multiscale.

SEU

FIRST Technology Development Plan: 4th Qtr. FY 1999 Actual: 4th Qtr FY 1999	Develop Key Technologies in the area of cryo-coolers, mixers, bolometer arrays, and light-weight 3.5-meter telescope to prepare for C/D start in FY 2000 and launch in FY 2006.
FIRST Instrument Performance Plan: FY 2000	Demonstrate performance of the Superconductor-Insulator-Superconductor (SIS) mixer to at least 8hv/k at 1,120 GHz and 10hv/k at 1,200 GHz. The U.S. contribution to the ESA FIRST is the heterodyne instrument, which contains the SIS receiver.
FIRST Technology Development Plan: FY 2001	Complete the qualification mirror (QM) fabrication.
GLAST Prototype Instrument Performance Plan: FY 2000	The prototype primary instrument for GLAST will demonstrate achievement of the established instrument performance level of angular resolution of 3.5 degrees across the entire 20-MeV (million electron volts) to 100-GeV (giga-electron volts) energy range.
GLAST Technology Development Plan: FY 2001	Conduct successful NAR for instrument development, project definition, and interface development.

Flight Validation Program

ST-5 Critical Design Review Plan: FY 2001	Complete ST-5 Critical Design Review.
ST-6, ST-7, and ST-8 Project Selections Plan: FY 2001	Competitively select two to three subsystem technology demonstrations.
ST-6 and ST-7 Project Approval Plan: FY 2001	Complete ST-6 and ST-7 project approval.
ST-6 Critical Design Review Plan: FY 2001	Complete ST-6 Critical Design Review (CDR).

Research Program

Space Science Research and Analysis

Issue FY 2000 NASA Research Announcement (NRA) Plan: February 2000	Issue FY 2000 NRA for Research Opportunities in Space Science (ROSS).
Issue FY 2001 NASA Research Announcement (NRA) Plan: 2nd Qtr., FY 2001	Issue FY 2001 NRA for Research Opportunities in Space Science (ROSS).
Astrobiology Institute Operations Plan: FY 1999 Actual: FY 1999	Initiate the Astrobiology Institute's operations by linking up to eight institutions and engaging approximately 50 investigators to promote publication of interdisciplinary research and foster effective public education and outreach on research on life in the universe. Eleven member institutions have established video and whiteboard conferencing capabilities, and over 70 investigators are engaged in research.
Astrobiology Research Plan: FY 2001	High-priority studies identified in the Astrobiology Roadmap will be carried out, the National Astrobiology Institute will conduct institute-wide functions using internet/video conferencing capabilities (ie. Executive council meetings, science seminars, group collaborations, education/outreach), and Institute research publications will reflect its interdisciplinary nature.

Suborbital Program

Balloon Program

Balloon Flights Actual: FY 1999	16 flights were flown with 94% balloon and mission success.
Balloon Flights Plan: FY 2000	Plans call for 26 worldwide balloon missions.
Balloon Flights Plan: FY 2001	Plans call for 26 worldwide balloon missions.

Sounding Rockets

Sounding Rocket Flights Actual: FY 1999	23 missions were launched with 100% success and 96% mission success.
Sounding Rocket Flights Plan: FY 2000	Plans call for 25 worldwide sounding rocket missions.
Sounding Rocket Flights Plan: FY 2001	Plans call for 25 worldwide sounding rocket missions.

ACCOMPLISHMENTS AND PLANS

Core Technology Program

Space Science Core

The Explorer Technology initiative will identify, develop, infuse and transfer technologies that enable and enhance opportunities for frequent scientific investigations at the highest science value per unit cost through Category III AO awards for technology development, NRAs, and partnering opportunities. MIDEX Category III awards, new partnering arrangements and Explorer Technology NASA Research Announcement (NRA) awards for technology development in instrument components, optical systems for instruments, data systems hardware and software, and guidance navigation and control were made in FY 1999. SMEX Category III awards, and more new partnering agreements are planned for FY 2000, as well as the issuance of a new NRA, with awards planned for FY 2001.

The Information Systems program will continue to provide reliable access for research communities and the public to obtain science data through the Planetary Data System, National Space Science Data Center, Space Telescope Science Institute, and High Energy Astrophysics Science Archive Research Center. Continuing advances in development and infusion of evolving information technology will increase the level of interoperability to support interdisciplinary research.

The Intelligent Systems program will complete a Non-Advocate Review (NAR) in FY2000. The program will begin development of intelligent agents (e.g. robotic teaming, vehicle health monitoring, etc.) and intelligent data mining tools during FY 2001. Work will also be initiated in such high payoff areas as: information displays and visualization tools for distributed collaboration; verification and validation algorithms for distributed computing architectures; automated reasoning and data interpretation methodologies for an advanced vehicle health monitoring system; advanced data mining and data fusion tools for distributed, massive data sets; methods and tools to emulate human cognitive skills for scientific discovery and mission operations; plus adaptive, learning-based control methods for enhanced aircraft safety. These activities will continue through the life of the program and will result in deliveries of fundamentally new capabilities throughout the FY 2001-2005 time period.

In High Performance Computing and Communication, the Remote Exploration and Experimentation project will continue to support the development of a first-generation testbed for scaleable spaceborne applications as well as embedded scaleable high-performance computers.

Science instrument development will continue to develop initial technologies for new sensors, detectors, and other instruments in support of specific space science research objectives. In many cases these technologies will be flown and validated as part of the suborbital program, either on balloons or rockets.

Planetary flight support will continue to develop the Advanced Multi-Mission Operations System ground system upgrade, which will enable greater efficiency in the monitoring of spacecraft systems allowing us continued operation at a reduced level of overall mission operations costs.

Cross-Enterprise Technology

Activities within the Cross-Enterprise Technology program continue to focus on reducing spacecraft size, weight, and operating costs. The following are among many accomplishments for FY 1999:

- In Advanced Power and On-Board Propulsion, supported flight validation (>3,500 hours) of the 2.6-Kilowatt Ion Propulsion Engine on DS-1 by accumulating more than 7,400 hours of successful life–cycle testing on the ground. This is the first use in space flight of a technology that has been in various stages of development for over 30 years. The technology will be used to reduce greatly the flight time and the cost of planetary missions and Discovery Program missions.

- In Thinking Space Systems funded ground-based activities in support of Flight validation of software for autonomous control of spacecraft. Known as Remote Agent, the software operated NASA's Deep Space-1 spacecraft and its futuristic ion engine during two experiments that started on May 17, 1999. For two days the Remote Agent ran on the on-board computer of Deep Space-1, more than 60,000,000 miles (96,500,000 kilometers) from Earth. The tests were a step toward robotic explorers of the 21st century that are less costly, more capable and more independent from ground control. Remote Agent is Co-Winner of NASA's 1999 Software of the Year Award.

- In Surface Systems, demonstrated that an innovative concept, the Subsurface Explorer, can, in a laboratory testbed, penetrate to a depth of at least 8 meters using only 100 Watts. This development of a small (20 kg), self-contained robotic device capable of penetrating significant distances underground, will enable exploration and sample return from the Nucleus of a Comet and from soil layers below the Mars permafrost.

- The Micro/Nano Spacecraft Thrust Program demonstrated in ground tests a prototype micro-star tracker — of low mass (< 1 kg) and low cost ($25K) — for attitude control of micro-spacecraft. It is aimed at replacing the state-of-the-art tracker weighing about 5kg and costing $400K.

- The Surface System Program field-tested a rover with inflatable wheels and inflatable solar arrays (8 kg, 40 Watts). The projected range of the rover is 10 km. This design permits climbing over obstacles as high as about 0.5 m with mass savings of well over an order of magnitude compared to a rigid design.

- The Ultralightweight Structures and Space Observatories Program developed a 1/2-scale model of the inflatable NGST sunshield to cool the telescope to cryogenic temperature passively. The inflatable structure enables a ten-fold reduction in launch volume and two-fold reduction in sunshield weight.

- In the Next Generation Infrastructure thrust, the Smart Assembly Modeler (SAM) is now in beta testing. SAM assembles flight engineering models from independently created – as well as platform independent -- part or component flight engineering models, allowing component design engineers to predict and assess how these independent subsystems will perform when integrated into a real system.

- Space Solar Power issued a NASA Research Announcement, made peer-reviewed awards in selected areas and initiated coordinated efforts at several NASA centers.

In FY 2000 work has commenced on two new items in the Cross-Enterprise Technology program: Gossamer Spacecraft, and Next Decade Planning. Gossamer Spacecraft has begun developing ultralight structures and other technologies required to demonstrate the deployment, control, and utility of thin-film deployable structures. Next Decade Planning is supporting the development and refinement of concepts and technologies that are critical to developing a robust set of civil space initiatives during the FY 2001 to FY 2010 timeframe. Examples of concepts that will be addressed by this initiative include: direct imaging of extrasolar planets, establishment of permanent robotic outposts on other worlds, human space flight in support of science goals at potential research site beyond low-Earth orbit, leveraging potential future commercial space infrastructure for research and exploration, and enabling the direct involvement of the public in space exploration.

The most recent Cross Enterprise Technology Development Program (CETDP) NASA Research Announcement (NRA) was released during the first quarter of FY 2000. The plan for the CETDP is to release one three-year NRA per year. It is anticipated that funding will be approximately $20M per year for each NRA. The total NRA funding will reach half of the CETDP funding level in FY 2002. This first NRA release represents a combination of the first (FY1999) and second (FY2000) NRAs. Current plans call for a single review of all proposals, followed by two sets of selections, one in the last quarter of FY 2000 and one in the first quarter of FY 2001. Over 2100 Notices of Intent have been received and the number is increasing daily. Indications are that the number of actual proposals could easily exceed 3000, which will be a record for the Office of Space Science. Proposals are due by Feb. 15, 2000.

Focused Programs

The Astronomical Search for Origins focused program continued technology development and mission design activities in FY 1999. Among the accomplishments were:

- SIM concept design down-select was made in October 1999. The decision is to go with the Classic Design. It should be noted that both the Classic and Alternative designs evolved and improved significantly as a result of the design competition.

- Selections and awards were made for Phase I of the NGST Advanced Mirror Technology concept studies in FY 1999. These studies will proceed into Phase II in FY 2000. In addition, NGST entered Phase A in early FY99, and will stay in Phase A throughout FY00.

- Construction continued on the KECK Outrigger domes and telescopes throughout FY 1999.

- Realignment of the ST-3 schedule to match TPF schedule requirements was completed in FY 1999. ST-3 entered Phase B in early FY 2000, and will enter into implementation in FY 2002.

The Origins focused program will fund mission design and technology development for six elements in FY 2000 and 2001:

- An interferometry technology validation flight (New Millennium Space Technology-3; formerly included in the flight validation program) to demonstrate the concept of separated spacecraft interferometry. This 6-month flight demonstration, scheduled for launch in 2005, will utilize two spacecraft to validate precision formation flying and space interferometry, technologies that are required for the Terrestrial Planet Finder (TPF) mission (see below).

- The Space Interferometry Mission (SIM) will be the world's first long-baseline operational optical space interferometer. It is scheduled for launch in FY 2006, assuming successful technology development. This mission has dual objectives: science and technology. The science objectives include: astrometric detection of planets around other stars in our galaxy (mostly those of Uranus' mass but also some as small as several Earth masses); and precision location of very dim stars to an unprecedented accuracy (SIM will be a factor of 250 better in accuracy on stars 1000-times fainter than the best catalog currently available). The technology objective is to serve as the precursor to the future interferometry-based TPF mission. Specific technologies to be developed include precision laser metrology, controlled optics, optical delay lines, vibration isolation and structural quieting systems, and deployable structures. An Announcement of Opportunity (AO) for SIM science instruments will be released in February 2000.

- The Next Generation Space Telescope (NGST) will combine large aperture and low temperature in an ideal infrared observing environment. NGST will allow astronomers to study the first protogalaxies, the first star clusters as they make their first generation of stars, and the first supernovae as they release heavy chemical elements into the interstellar gas. New technologies

include precision-deployable structures, very large, low-area-density cold mirrors and active optics, and low-noise, large format infrared detectors. The target launch date is FY 2007, also assuming successful technology development.

- Keck Interferometer Phase 1 enables NASA to capitalize on its significant previous investment in the Keck Observatory in Hawaii by connecting Keck's twin 10-meter telescopes into an 85-meter-baseline interferometer. Installation of the Beam-Combining hardware on Mauna Kea was initiated in FY 2000. The first test fringes from the combined telescopes are planned by the end of FY 2000. When Phase 1 is completed in the fall of 2000, the Keck interferometer will become the world's most powerful ground-based optical instrument. Keck will be able to directly detect hot planets with Jupiter-size masses and will also be able to characterize clouds of dust and gases permeating other planetary systems. Phase 2 will add four 1.8-meter outrigger telescopes to the interferometer complement which will allow astrometric detection of Uranus-sized planets and will provide the capability to image protoplanetary discs. Phase 2 is planned for completion in FY 2002.

- Terrestrial Planet Finder (TPF) is aimed at the ultimate goal of the NASA's Origins program: to find Earth-like planets. Each of the precursor Origins activities, including the Space Infrared Telescope Facility (SIRTF), provides knowledge and technology needed for the design of the TPF. As currently envisioned, TPF will either be a large single-spacecraft interferometer or a group of several spacecraft (possibly copies of NGST) flown in precise formation. Thus, the experience and understanding gained in each step of the Origins program will be needed to make TPF successful. A request for proposals was released for TPF architecture studies in January 2000. Award is planned for three 18-month studies in April 2000.

- The Optical Interferometry Laboratory at the Jet Propulsion Lab will enable the development and verification of interferometry systems operating at the extremely high levels of precision required to meet the objectives of the Origins program. The new facility will include a high bay, a low bay, a ground support equipment room and three development laboratories.

The Advanced Deep Space Systems focused program will continue to provide for the development, integration, and testing of revolutionary technologies for solar system and planetary exploration. Technologies developed in this area will also support a Solar Probe mission, which utilizes many of the same systems and technologies as the Europa Orbiter and Pluto/Kuiper projects. The primary focus of the Deep Space Technology Program is to reduce the mass and volume of planetary spacecraft, toward the goal of a "spacecraft on a chip."

In FY 1999, CISM completed fabricating the 1st generation system on a chip prototype at MIT Lincoln Labs and delivered it to JPL for performance testing. Also during FY 1999, NASA completed development of university curricula for two CISM technology thrust efforts: Curriculum for Systems on a Chip, and Curriculum for Revolutionary Computing Technologies. X2000 delivered an integrated and tested spacecraft avionics testbed design during FY 1999. This testbed is now being prepared for operational use. Europa/Pluto initiated Phase A mission design studies and technology development in FY 1998 and continued the studies and technology activities throughout FY 1999. These missions entered phase B in early FY 2000 and will complete formulation phase by the end of FY 2000.

The ST-4/Champollion project was cancelled on July 1, 1999. NASA took this action to ensure that the Space Science program has sufficient financial resources to manage its remaining programs and projects within its projected budget availability. This mission was a relatively low priority in the Space Science program for three reasons. First, it was not required to achieve the objectives in the Space Science Strategic Plan. Second, some of the most important science that would have been done on ST-4 will be accomplished by the European Rosetta mission. Finally, the ST-4 mission had gradually moved away from the original intention of the Flight Validation Program, which is to validate emerging technologies to enable science missions. By terminating the current ST-4 mission, we will achieve a net savings of greater than $200 million in the FY 1999 - FY 2004 timeframe. We have preserved the technology validation objectives of ST-4 that are required for the Mars Surveyor Program and the Europa Orbiter by applying a portion of the savings from ST-4 to those programs.

Key technology partnerships will be maintained with national laboratories and research agencies such as:
- Air Force Research Labs to develop radiation-hard microelectronics technology
- Sandia National Laboratory to support MEMS technology
- Department of Energy to support Stirling thermal-to-electric conversion technology
- MIT Lincoln Labs to continue advanced semiconductor technology
- DARPA to continue ultra-scale computing and quantum computing technology

Emphasis will be on micro-avionics, autonomy, computing technologies and advanced power systems. The development of AMTEC thermal-to-electric conversion technologies in the Advanced Radioisotope Power System (ARPS) project was terminated during FY 1999 due to a lack of sufficient technical progress. The Advanced Power Systems project is being refocused in FY 2000 to pursue alternate technologies, such as Stirling conversion systems. The focus of this activity is to develop a robust, high-efficiency, low-mass, low–cost, 100-watt-class electrical power source for deep space missions, along with supporting technologies for radioisotope power sources in the milliwatt and 10-watt classes for future projects. Performed in partnership with the Department of Energy (DoE), this activity will increase the efficiency of thermal-to-electric converters, reduce the cost and time to fabricate, test and deliver flight power systems, and provide breakthrough technology and/or multifunctional radioisotope power sources for future microspacecraft.

Since FY 1998, the Center for Integrated Space Microsystems (CISM) has been developing the advanced computing and avionics technologies that will enable miniaturized autonomous robotic spacecraft for deep-space exploration. These technologies will comprise the core of the advanced spacecraft development. A world-class facility for microelectronics system design, advanced simulation, rapid prototyping, and integration and test was started at JPL in FY 1999, and is being completed in FY 2000. This facility will be electronically linked to industrial partners and collaborating universities as part of the distributed Collaborative Engineering Workbench technology.

Mission planning will support design and definition of the Europa Orbiter mission and the Pluto/Kuiper Express mission. The formulation efforts for both these projects will be completed during FY 2000. Due to changes in the power systems design and increases in the launch vehicle costs, the launch schedule for these missions is being re-evaluated.

The focus for Sun-Earth Connections mission planning and technology activities will be directed toward the following future missions:

- Living With a Star is a set of missions and enhancements to current programs designed to study solar variability and its effects on humanity. This project will establish a Solar Dynamics Observatory, Solar Sentinals, Geospace Dynamics Network and initiate data analysis and modeling targets for space weather objectives. LWS will include partnerships with other federal agencies, including the National Science Foundation, United States Air Force, and National Oceanic and Atmospheric Administration.

- Solar-B, a joint mission with the Japanese (ISAS spacecraft and launch), consists of a coordinated set of optical, EUV, and X-ray instruments that will apply a systems approach to the interaction between the Sun's magnetic field and its high-temperature, ionized atmosphere. Technologies required by this mission include lightweight, stable optics and high-accuracy polarimetry for high-resolution (~0.1 arc sec) measurements of solar magnetic fields. Solar-B's expected launch date is FY 2004.

- STEREO is conceived as two spacecraft in solar orbit. These spacecraft are to provide stereo imaging of solar corona, track solar mass ejections from the Sun to Earth using radio and optical instruments, and measure in-situ the solar wind and energetic particles (solar mass ejections appear to be a primary source of intense solar energetic particles events). STEREO's anticipated launch date is FY 2004.

- Solar Probe, the first close fly-by of a star (within 4 solar radii), requires a thermal shield to protect the payload from the Sun without releasing material that would contaminate the in-situ measurements. Because of its deep space flight trajectory, Solar Probe also requires many of the technologies being developed within the Advanced Deep Space Systems focused program, such as radiation hardening for the Jupiter swing-by and solar fly-by. The target launch date is FY 2007.

- Magnetospheric Multiscale is to be comprised of five spacecraft flying in formation, to study simultaneously the global behavior of the magnetosphere and the magnetospheric processes at the small scales where many of the basic interactions occur.

- Global Electrodynamics is a mission made up of four spacecraft, which will have an "atmospheric dipping" capability for investigating the electromagnetic coupling between the solar wind and upper atmosphere.

- Magnetospheric Constellation will support a fleet of 10-100 nanosats using radio tomography and in-situ instrumentation to provide instantaneous global maps of plasma and field structures in the magnetosphere.

Structure and Evolution of the Universe mission planning and technology activities focus on development and demonstration of technologies necessary to implement the space missions outlined in the recent SEU Science and Technology Roadmaps. The priority missions include:

- Gamma Ray Large Area Space Telescope (GLAST). GLAST will study cosmic sources of high-energy particles and radiation (up to 300 GeV) with a large area, wide field-of-view, imaging telescope, using solid-state particle tracking technology. This technology is being developed in cooperation with DOE.

- ESA's Far Infrared and Submillimeter Space Telescope (FIRST). The U.S. participation on the FIRST mission substantially enhances the science goals with four key technologies: lightweight telescopes, cryocoolers, bolometer arrays, and heterodyne receivers.

- Constellation X-ray Mission. Constellation-X will use multiple satellites to enable a very large collecting area. Each spacecraft will be equipped with a high-throughput telescope for the low-energy band up to 10 keV, and three grazing-incidence telescopes for the high-energy band.

Flight Validation

The DS-1 spacecraft successfully flew by asteroid Braille in July, successfully completed its primary mission of testing twelve advanced technologies in late September 1999 and is now on an extended mission. The mission has exceeded almost all of its technology validation requirements by conducting more extensive tests than had been planned,. As one dramatic example, the spacecraft's experimental xenon ion engine, which was required to thrust for a minimum of 200 hours, has been operated for nearly 1,800 hours.

The two DS-2 miniature probes carrying ten experimental technologies were to have impacted Martian soil on December 3, 1999 but each probe failed to respond to communication efforts by NASA engineers. Review boards have been set up to study the cause of the apparent loss and explore ways to prevent a recurrence.

The Flight Validation program has been refocused to maintain its emphasis on technology validation, risk mitigation, and rapid infusion of technology into science missions through a competitive process. Additional funding has also been provided in FY 2001-2005. Three very small satellites called the Nanosat Constellation Trailblazer mission were selected in August 1999 as the NMP Space Technology-5 (ST-5) demonstrator. Each Trailblazer spacecraft will be an octagon 16 inches across and 8 inches high, and each will have booms and antennas that will extend after launch. Results from the Trailblazer mission will be used to design future missions using constellations of lightweight (about 44 pounds), highly miniaturized autonomous spacecraft. With the funding added to the program, it is anticipated that 2-3 subsystem technology demonstrations will be competitively selected in FY 2001 and each year thereafter, and that two small system demonstrators and one medium-sized demonstrator will be competitively selected and developed in the 2001-2005 period.

Research

Research and Analysis

The Space Science R&A program continued to produce exciting scientific results in 1999. Many of the recent discoveries of planets around other stars were supported by NASA's Space Science R&A program. Particularly exciting was the announcement of the first known multi-planet system around a sun-like star. In addition, evidence was presented for a planet in orbit around a pair of stars. By the end of 1999, the number of known planets around other stars reached nearly 30. While the potential detection of Earth-like planets remains in the future, per our plans for the Origins program, these findings increase the likelihood that such planets may be common in the universe, and are already leading to advances in theoretical models of planetary system formation.

Research continues on the Martian meteorite ALH84001 with most findings pointing to a non-life origin of many of the features. However, there are still several lines of mineralogical evidence that may point to life processes (e.g., origins of some of the iron oxides). The team that presented the evidence in 1996 for past Mars life in ALH84001 announced in 1999 that they had found similar features in two other Martian meteorites. In other meteorite news, scientists announced the discovery of liquid water in two different meteorites, probably a remnant of the solar system's fiery beginning and a possible clue to how the sun and planets formed. A rock-hunting robot was dispatched to Antarctica in December, in an attempt to turn up the first meteorites discovered by a machine rather than a human. This capability would enhance the future collection of meteorites in Antarctica, and could have future implications for autonomous robots on other solar system bodies.

The Near-Earth Object (NEO) Program Office at JPL continues to focus on the goal of locating at least 90 percent of the estimated 2,000 asteroids and comets that approach the Earth and are larger than about 2/3-mile (about 1 kilometer) in diameter, by the end of the next decade. These are objects that are difficult to detect because of their relatively small size, but are large enough to cause global effects if one hit the Earth. Detection, tracking, and characterization of such objects are all critical. The Near-Earth Asteroid Tracking (NEAT) project has been enhanced by the addition of high-tech, computerized electronic upgrades to an existing telescope with a much greater field of view than the one previously used by NEAT. The fastest rotating asteroid ever found, spinning on its axis every 11 minutes, was announced by an international team of astronomers. Finally, scientists using radar data created the best image ever of a near-Earth object.

In recognition of the interrelationship between the origin and evolution of life and the origin and evolution of planets, a new program within the framework of Astrobiology was initiated in 1997. A multi-disciplinary Astrobiology Institute was established with members from 11 geographically distributed research institutions, linked through advanced telecommunications. Examples of research accomplishments for the past year include a genetic study demonstrating that the ancestors of major groups of animal species may have begun populating Earth 1.2 billion years ago, more than 600 million years earlier than indicated by their fossil remains. It was demonstrated that methanogenic bacteria could grow in conditions simulating the subsurface of Mars if even a small amount of water is available. And a microbial world was discovered hidden deep beneath the frozen Antarctic ice; this could help us learn more about how life can survive under extreme conditions on other planets or moons.

NASA is considering construction of a unique national lab at Ames Research Center, built by an industry consortium. This facility would complement the Astrobiology Institute, and would be dedicated to simulating and analyzing the chemical and biological characteristics of detectable, habitable worlds. The facility would be open to the community through competitive, peer-reviewed selection.

Data Analysis

NASA's Space Science spacecraft continue to generate a stream of scientific discoveries. Many of these findings are of broad interest to the general public, as demonstrated by widespread media coverage. Recent highlights include results from Hubble Space Telescope, Mars Global Surveyor, Cassini, Compton Gamma-Ray Observatory (CGRO), Galileo, Transition Region and Coronal Explorer (TRACE), Advanced Composition Explorer (ACE), Solar and Heliospheric Observatory (SOHO), Wind, Polar, the Solar Anomalous and Magnetospheric Participle Explorer (SAMPEX), and the Lunar Prospector. However, many other Space Science spacecraft have been "in the news" and extremely scientifically productive as well. NASA is also finding ways to partner with the education community in order to strengthen science, technology, and mathematics education. Listed below are the top science stories of the past year from NASA Space Science missions.

- EXPANDING UNIVERSE. In addition to the thousands of breathtaking images that the Hubble Space Telescope (HST) continued to deliver, one result was a long-awaited, scientific coup: Hubble scientists calculated a more accurate value for how fast the universe is expanding after eight years of painstaking measurement. The rate of expansion, called the Hubble Constant, is essential to determining the age and size of the universe. Measuring the Hubble Constant was one of the three major goals for the telescope when it was launched in 1990.

- LATEST FROM MARS. Mars Global Surveyor Provided the First Global 3-D Map of Mars. An impact basin deep enough to swallow Mount Everest and surprising slopes in Valles Marineris highlight a global map of Mars that will influence scientific understanding of the red planet for years. Generated by the Mars Orbiter Laser Altimeter (MOLA), the high-resolution map represents 27 million measurements gathered in 1998 and 1999.

- JOURNEY TO SATURN. The Cassini spacecraft, currently on a journey to Saturn, completed a highly accurate swing-by of Earth in August. This was necessary to give Cassini a boost in speed, sending it toward a rendezvous with Saturn and its moon Titan in 2004. Cassini's next encounter will be with Jupiter in December 2000 as the giant planet provides the last gravitational assist to the spacecraft on its journey to Saturn.

- IMAGES OF AN EXPLODING UNIVERSE. Astronomers racing the clock managed to take the first-ever optical images of one of the most powerful explosions in the Universe -- a gamma ray burst -- just as it was occurring on January 23, 1999 Such bursts occur with no warning and typically last for just seconds. The science team was alerted to the new gamma ray burst by the Compton Gamma Ray Observatory (CGRO) and, within 22 seconds, was able to capture an image of the burst at optical wavelengths. Discoveries like this are essential to unlocking the secrets of our universe.

- CRAB NEBULA. In July, the Space Shuttle Columbia successfully carried to orbit the Chandra X-Ray Observatory (CXO), the third of NASA's "Great Observatories," joining the Hubble Space Telescope and the Compton Gamma Ray Observatory. The results to date from Chandra have been dramatic. After barely two months in space, CXO took a stunning image of the Crab Nebula, the most intensively studied object beyond our Solar System, and revealed something never seen before: a brilliant ring around the nebula's heart. Its performance and images continue to delight astronomers.

- OUR STAR, THE SUN. A new feature near the surface of the Sun, termed "solar moss" because its weird, sponge-like appearance resembles the plant, has been discovered by the Transition Region and Coronal Explorer (TRACE) spacecraft. Solar Moss is a thin region in the solar atmosphere where the temperature soars from ten thousand to millions of degrees. This discovery offers a new way to study the mass and energy flows in this region. It also helps us understand how the large magnetic loops in the Sun's outer atmosphere, the corona, form out of the highly intermittent magnetic fields on the Sun's surface. Studying the solar moss may ultimately shed light on the long-standing problem of how the corona is heated to million-degree temperatures.

- IMAGES OF IO FIERY LAVA. Galileo is getting close-in looks at Io, Jupiter's closest satellite. During a recent close flyby of Io, the spacecraft observed a fiery lava fountain shooting more than a mile above the moon's surface. The images show a curtain of lava erupting within a giant volcanic crater.

- SOLAR WIND AND THE AURORAL DISPLAY AT THE NORTH POLE. From May 10-12, 1999, the solar wind that blows constantly from the Sun virtually disappeared in the most drastic and longest-lasting decrease ever observed. Dropping to a fraction of its normal density and to half its normal speed, the solar wind died down enough to allow physicists to observe particles flowing directly from the Sun's corona to Earth. This severe change in the solar wind also drastically changed the shape of Earth's magnetic field and produced a rare auroral display at the North Pole. The following missions provided the data on this unusual event: ACE, SOHO, Wind, Polar, Geotail, IMP-8, SAMPEX, and Lunar Prospector.

Suborbital Program

In FY 1999, 16 balloons were flown for the core program, of which 15 were successful flights. The unsuccessful flight was reflown successfully within 10 days. Capping years of technology development, the long duration ballooning (LDB) capability has been repeatedly demonstrated and is now fully operational. Work is underway to demonstrate an ultra-long duration capability in 2001. Collaboration work with JPL is focusing on ULDB technologies that could be useful for planetary exploration programs such as Mars or Venus. The first demonstration of a 60,000 m^3 (ULDB) super-pressure balloon was launched in October 1999.

The sounding rocket program achieved 100% flight and 96% science success in FY 1999. Additionally, an active campaign in Norway occurred during this period. Work on the sounding rocket operations procurement resulted in announcement of an award in December 1998. The transition to this new approach toward managing the program was successfully demonstrated in FY 1999.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE SCIENCE INVESTMENTS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Enterprise Contribution to Academic Programs	[10,200]	[10,200]	13,200
Education Program			1,500
Minority University Research and Education Program	[10,200]	[10,200]	11,700
Total	[10,200]	[10,200]	13,200

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Space Science mission holds for students and educators. The unique character of Space Science exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with Space Science Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of Space Science activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

The Space Science Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Space Science Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Space Science Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the

Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

SCIENCE, AERONAUTICS, AND TECHNOLOGY APPROPRIATION

LIFE AND MICROGRAVITY SCIENCES & APPLICATIONS

FY 2001 CONGRESSIONAL BUDGET ESTIMATE

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Advanced Human Support Technology (AHST)	24,500	30,215	30,900	SAT 2-7
Biomedical Research & Countermeasures (BR&C)	59,700	57,192	76,900	SAT 2-10
[Construction of facilities]	[3,500]	[9,000]	[8,500]	
Fundamental Biology (FB)				SAT 2-13
(Formerly Gravitational Biology and Ecology (GB&E))	40,900	38,200	39,200	
Microgravity Research (MR)	113,700	108,800	129,260	SAT 2-15
Space Product Development (SPD)	15,400	14,400	13,600	SAT 2-19
Health Research (HR)	7,600	8,700	11,300	SAT 2-23
(Formerly Occupational Health Research (OHR) and Space Medicine Research (SMR))				
Mission Integration (MI)	1,700	17,214	240	SAT 2-28
Investments (MURED from BR&C in FY 1999 and in FY 2000)	[1,000]	[1,000]	1,000	SAT 2-31
Total	263,500	274,721	302,400	
Distribution of Program Amount by Installation				
Johnson Space Center (JSC)	76,999	94,458	124,109	
Kennedy Space Center (KSC)	5,808	5,465	4,559	
Marshall Space Flight Center (MSFC)	63,613	53,163	61,387	
Ames Research Center (ARC)	34,099	32,651	36,185	
Langley Research Center (LaRC)	429	52	35	
Glenn Research Center (GRC)	38,891	39,377	37,348	
Goddard Space Flight Center (GSFC)	11,069	10,324	6,776	
Jet Propulsion Laboratory (JPL)	12,881	10,484	13,988	
Headquarters (HQs)	19,711	28,747	18,013	
Total	263,500	274,721	302,400	

GENERAL

The Life and Microgravity Sciences and Applications (LMSA) program is an integral component of NASA's Human Exploration and Development of Space (HEDS) Enterprise. The projects supported by the LMSA program through ground- and space-based basic and applied research, seek to advance scientific and commercial knowledge, to enable the development of space for human enterprise, to create new products and services through space research, and to transfer the knowledge and technologies developed as broadly as possible within the United States. We seek to enable and exploit the possibilities of human space flight to improve the quality of life for people on Earth.

PROGRAM GOALS

The Office of Life and Microgravity Sciences and Applications (OLMSA) plays a primary role in the pursuit of the following goals and objectives of HEDS and a secondary role in the pursuit of other HEDS goals. OLMSA provides key products for the following five general goals of the enterprise.

Goal: Expand the Frontier.

Objective- Enable human exploration through collaborative robotic missions.

Goal: Expand Scientific Knowledge.

Objective – Investigate chemical, biological and physical systems in the space environment, in partnership with the scientific community.

Goal: Enable and establish permanent and productive human presence in Earth orbit.

Objective – Ensure the health, safety and performance of humans living and working in space.

Goal: Expand commercial development of Space.

Objective –Facilitate access to space for commercial researchers.
Objective – Foster commercial participation on the International Space Station.

Goal: Share the experience and discovery of human Space flight.

Objective – Advance the scientific, technological and academic achievement of the Nation by sharing our knowledge, capabilities and assets.

Outcomes:

OLMSA seeks to advance scientific knowledge, to enable the development of space for human enterprise, and to transfer the knowledge and technologies that we develop as broadly as possible. We seek to enable and exploit the possibilities of human space flight and to improve the quality of life for people on Earth. Among the ultimate outcomes of our work are:

expanded fundamental knowledge;
improved health and human performance on earth and in space;
improved industrial processes;
expanded commercial activity in space; and
enhanced capabilities for humans to live, work and explore in space.

STRATEGY FOR ACHIEVING GOALS

OLMSA pursues the goals described above through the following projects, which focus on specific fields of research:

Advanced Human Support Technology (AHST)

- Provides cutting edge technologies for the support of humans in space.

Biomedical Research and Countermeasures (BR&C)

- Contributes to the health, safety and performance of space crews.
- Investigates the biomedical effects of space flight to provide the biomedical bases for future human exploration and development of space.

Fundamental Biology (FB) (formerly Gravitational Biology and Ecology (GB&E))

- Investigates the interaction between gravity and basic biological processes using living systems, ranging from simple cells to humans, in space and on the ground.

Microgravity Research (MR)

- Uses the environment of space to explore the nature of physical, chemical, and biological processes contributing to progress in science and technology on Earth.
- Studies the role of gravity in technological processes, building a scientific foundation for understanding the consequences of gravitational environments beyond Earth's boundaries.

Space Product Development (SPD)

- Facilitates the use of space for commercial products and services.
- Couples NASA and private sector technology development to the advantage of both.

Within each of these projects, OLMSA supports fundamental and applied research driven by an emphasis on expanding scientific and commercial knowledge and disseminating the research database as widely as possible to the American research and technology and commercial communities. Mission-driven research improves knowledge and technology for human space flight and exploration. Applications-driven research seeks to increase industrial involvement and transfer knowledge, expertise and technology to an appropriate partner or partners.

In addition, OLMSA is an operational organization conducting the following functions:

Health Research (HR)

- Space Medicine Research (SMR)
  - Ensures the delivery of clinical care in support of human space flight.
  - Establishes requirements for medical care and medical research to support human space flight.
- Occupational Health Research (OHR)
  - Contributes to the health, well being, safety, and productivity of the NASA workforce.

Mission Integration (MI)

- Integrates research missions involving human space flight.

OLMSA's program of research and technology development relies upon broad participation by researchers from academia, other government agencies and departments, nonprofit and commercial sectors, NASA's Commercial Space Centers (CSCs), NASA Specialized Centers for Research and Technology, and NASA Field Centers. In selecting investigations and projects for support, and ultimately for access to space, OLMSA follows different, but closely related processes for scientific research, for commercial research, and for technology research and development.

OLMSA uses ground-based research to develop and refine concepts for space experiments and to create a framework of knowledge and expertise in which the full scientific value can be realized. It utilizes the nation's academic and industrial resources, joining prominent researchers with NASA expertise in multidisciplinary microgravity experimentation. In support of the science community, the program also finances unique gravitational simulation facilities such as centrifuges, parabolic aircraft, drop towers/tubes, and other specialized support facilities and technologies such as chambers, bed rest studies, and data archiving. All non-commercial research is conducted on an open, competitive, peer-reviewed research solicitation process including the regular release of NASA Research Announcements (NRAs) in specific disciplines and reviews of proposals by independent panels of experts.

In addition to regular solicitations (NRAs), OLMSA is breaking new ground by fostering research in Biologically-Inspired Technology through dedicated NRAs. NASA has embarked on a focused program to develop advanced technologies that are critical for long duration space flights to monitor human health in a non-invasive manner. These advanced technologies are expected to confer significant benefits to medical care on Earth. Such biologically-inspired technologies will provide products which have features of biology embedded within them such as self-assembly, self-repair, fault tolerance, low energy needs and nanometers in feature size. The products from this research could have significant benefits on Earth, by enabling early detection of diseases. NASA is collaborating with the National Cancer Institute in this research and is actively seeking partnerships with other Federal Agencies to advance the field of nanotechnology.

Commercial research is supported through NASA-sponsored Commercial Space Centers' ground-based capabilities, as well as KC-135 aircraft for commercial research efforts that do not require extended duration microgravity. The Commercial Space Center ground and aircraft-based activities also support precursor research for the extended duration microgravity environment of Shuttle missions and the International Space Station. Commercial research initiatives are evaluated against established selection criteria including leveraged commitment from the private sector, clear product development goals, technical feasibility, and a market assessment.

OLMSA implements its space-based research on robotic free-flying vehicles, Space Shuttle missions in which experiments use pressurized carriers (i.e. SpaceHab) and/or unpressurized carriers (i.e., IMPESS pallet, Hitchhiker, Get-Away-Special carriers, or other unique support structures) that fly in the cargo bay as well as the Shuttle Middeck for small payloads, and, in the future, on the ISS. OLMSA employs this array of flight platforms in support of the broader strategic goals enumerated above. OLMSA does not employ a separate research selection track for mission oriented research. It maintains a queue of worthy research, to manifest as opportunities become available.

Bioastronautics Initiative

An important element of the Administration's Science and Technology (S&T) Initiative is in the field of biomedical research with NASA. With increased funds from the S&T Initiative, OLMSA will enhance and integrate activities already underway, creating a Bioastronautics Initiative that will ensure the health, safety, and performance of humans in space by accelerating research and development of "countermeasures" (diagnostics, therapy, preventatives, and rehabilitation methods) to maintain the health of flight crews on long duration missions and transfer this knowledge and technology to benefit health on Earth. Bioastronautics research is an interdisciplinary set of focused research activities bringing together biology, physics, chemistry, communications technology and nano-technologies that will revolutionize medical care delivery in space and on Earth. This research will produce technologies that will benefit health care such as: non-invasive or minimally invasive diagnostic systems, autonomous medical care delivery systems including robotic surgical capabilities, environmental control systems that are human-centered, providing rapid feedback and by detecting microbial, toxic and other environmental hazards, wearable sensors allowing autonomy and mobility, and portable, light-weight, compact health-monitoring systems applicable to space or ground situations. NASA's need for ensuring human safety, health and performance in space serves as a forcing function in many of these important technological development areas. OLMSA is engaging other Federal agencies, private and academic sectors to partner with NASA to explore these exciting areas. These partnerships will leverage and accelerate NASA's investments, and will also ensure a rapid transfer of this technology to the private sector.

A significant portion of the Bioastronautics Initiative will support biomedical research and development work sponsored by the National Space Biomedical Research Institute (NSBRI). The Institute's current research program focuses on twelve areas – bone loss; cardiovascular alterations; human performance and sleep; immunology, infection and hematology; muscle changes; balance problems; radiation effects; technology development; neurobehavioral and psychosocial factors; nutrition, physical fitness and rehabilitation; smart medical systems; and integrated human function. The technology aspect of this program will rely on our cooperative activities in these disciplines working together with NIH and other organizations as appropriate to leverage resources, ensure technology transfer for health care, and enhance synergism. The OLMSA projects contributing to this Initiative are AHST, BR&C, MR and HR (SMR). NASA is currently evaluating options for and benefits of integrating facilities and capabilities where astronauts, medical professionals, scientists, engineers, and operational specialists could interact as a team in accomplishing this bioastronautics initiative.

FY 2001 Funding for Bioastronautics Initiative	FY 1999 OPLAN	FY 2000 OPLAN	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Advanced Human Support Technology (AHST)	--	--	[2,000]
Biomedical Research & Countermeasures (BR&C)	--	--	[29,000]
Microgravity Research (MR).....	--	--	[11,000]
Health Research (HR) (formerly Occupational Health Research and Space Medicine Research (SMR))			[3,000]
Total Bioastronautics	--	--	[45,000]

BASIS OF FY 2001 FUNDING REQUIREMENT

ADVANCED HUMAN SUPPORT TECHNOLOGY

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Advanced Human Support Technology (AHST)	24,500	30,215	30,900

GOALS

The goals of AHST are: (1) to demonstrate and validate full self-sufficiency in air, water, and food recycling technology for use in space vehicles; (2) to demonstrate and validate integrated, fully autonomous environmental monitoring and control systems; and (3) to validate human factors engineering technology and protocols to ensure maintenance of high ground and flight crew skills during long-duration missions. AHST makes NASA technologies available to the private sector for Earth applications.

STRATEGY FOR ACHIEVING GOALS

AHST includes Advanced Life Support Systems (ALS), Space Human Factors (SHF), and Advanced Environmental Monitoring and Control (AEMC). ALS develops advanced regenerative life support technologies and systems by combining biological, physical, and chemical processes capable of producing and recycling the food, air, and water needed to enable long-term human missions in space in a safe and reliable manner while minimizing the need for resupply. SHF develops technologies that integrate the human and system elements of space flight and encourages mission planners to use human factors research results and technology developments to improve mission results and crew safety. AEMC develops new technologies, chemical and biological environmental sensors for air and water monitoring and microbial detection, as well as refining and micro miniaturizing currently available sensors.

Center Support

JSC is the lead center for implementing the AHST program. JSC coordinates all supporting center activities, manages ALS facilities, and conducts all system-level integration and testing for ALS. KSC manages extramural research and conducts specific research tasks directed at using plants in ALS systems. ARC manages extramural research and conducts specific research tasks directed at analytical models and physicochemical processes for ALS systems. JPL is the lead for the AEMC activities bringing their personnel and industry contacts to the development of sensors and monitoring capability.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1999. Complete 1999 data will be available in February 2000 with publication of the 1999 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1999		FY 2000		FY 2001
	Plan	Actual (est.)	Plan	Revised	Plan
Number of Principal Investigations	70	70	77	77	84
Number of Co-Investigators Supported	138	168	152	160	165
Number of Refereed Publications	69	70	76	75	77

ACCOMPLISHMENTS AND PLANS

FY 99 Advanced Human Support Technology (AHST)

- **New Food Technology Center:** OLMSA established a new Food Technology Commercial Space Center in partnership with industry. The Center will perform research that could lead to better food for astronauts and safer, more nutritious, longer shelf life packaged foods for everyone.
- **Life support research facility construction:** OLMSA completed construction of the BIO-Plex facility at JSC, including construction and installation of the interconnecting tunnel and airlock for the four chambers and ground support utilities. NASA will use the facility to develop advanced human support technologies and systems to conduct biomedical, space medicine and human factors research.
- **Electronic Nose demonstrated in flight:** An Electronic Nose Flight Experiment successfully demonstrated an efficient, new approach to spacecraft atmosphere monitoring on STS-95.
- **Wireless Augmented Reality Prototype:** OLMSA completed an integrated Wireless Augmented Reality Prototype (WARP) technology demonstration. This technology will support improved communications, health monitoring, and training on the International Space Station through "virtual reality" technology. Several copies of these devices have already been acquired by the private sector.

In FY 2000 AHST plans to complete the first phase (including utilities outfitting of three test chambers) of the BIO-Plex facility which will provide the capability to conduct a series of long-duration, human-in-the-loop, advanced technology tests over the next six years. AHST will demonstrate key technology capabilities for human support such as advanced techniques for water processing using microbes, waste processing using biological degradation and fluidized bed incineration, a no-expendable trace gas contaminant control system, solid waste processing, and flight test a miniature mass spectrometer. A Commercial Space Technology Center will be established in the area of Environmental Systems.

In addition, in response to direction in the FY 2000 appropriation, AHST includes $0.915M to the "Garden Machine Program" at Texas Tech University. The "Garden Machine" is a small, environmentally controlled and monitored plant growth chamber, developed by NASA ARC, and transitioned to Texas Technological University (TTU) by NASA JSC.

In FY 2001, NASA will release the annual AHST NRA and expand ground research to prepare to take advantage of the growing ISS capability. Candidate technologies, including sensor technologies, for the BIO-Plex facility will be selected and the major test support systems buildup will continue. An engineering breadboard/prototype of a Vapor Phase Catalytic Ammonia Removal water recovery subsystem will be developed for integrated evaluation at JSC. A flight test of the Immobilized Microbe Microgravity Water Processing System will be conducted. A Preliminary Design Review for the ISS Integrated AHST Facility will be conducted. Ground tests of Space Human Factors equipment, including the Wireless Augmented Reality Prototype, will be conducted.

BASIS OF FY 20001 FUNDING REQUIREMENT

BIOMEDICAL RESEARCH AND COUNTERMEASURES

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Biomedical Research and Countermeasures (BR&C)	59,700	57,192	76,900
Construction of Facilities	[3,500]	[9,000]	[8,500]
Minority University Research and Education Program	[1,000]	[1,000]	

GOALS

The goals of BR&C are to conduct research that (1) defines and reduces risk to crew health from space radiation; (2) defines and reduces risk of acute and chronic health problems, including psychological and behavioral problems; (3) will increase crew productivity in flight, and ensures crew resumption to full, healthy life on Earth; and (4) transfer biomedical knowledge and technology gained through research on the ground and in space to the Earth-based medical community.

STRATEGY FOR ACHIEVING GOALS

BR&C includes research on physiology, behavior and performance, biomedical countermeasures, operational and clinical problems, environmental health, and radiation health. BR&C is the primary OLMSA discipline for the Bioastronautics initiative, receiving the bulk of the Bioastronautics funding, in order to expand teams and task activities in the National Space Biomedical Research Institute (NSBRI). BR&C seeks to characterize and determine the mechanisms of physiological changes in weightlessness, including those that threaten to limit the duration of human space missions. It also develops methods that allow humans to live and work in microgravity, optimize crew safety, well being and performance, and minimize the deleterious effects of returning to earth's gravity after space flight. It 1) provides scientific knowledge required to specify, measure, and control spacecraft environments; 2) develops standards and countermeasures, where necessary, to optimize crew health, safety, and productivity; (3) develops monitoring techniques, procedures, and standards for extended missions; and (4) establishes the scientific basis for protecting humans engaged in the development and exploration of space from radiation hazards.

Center Support

JSC is the Lead Center for implementing the BR&C Program. ARC and KSC provide supporting center activities to JSC. JSC also manages the significant ground-based grant activities and all flight experiment activities focused on human research. ARC supports biomedical research investigations and plays the primary life sciences role in the development of biomedical flight experiments that require non-human subjects. KSC provides pre- and post-flight support for BR&C flight experiments. A countermeasure-focused

research program is managed by a cooperative agreement between NASA JSC and Baylor College of Medicine. This cooperative agreement established the National Space Biomedical Research Institute (NSBRI), as a seven university consortium managed by Baylor College of Medicine and JSC, to accomplish integrated, critical path biomedical research and countermeasures development. The NSBRI will play an important role in the Bioastronautics Initiative, providing a direct link to many of the nation's top biomedical research universities. The NSBRI expanded its team in FY2000 from seven to twelve consortium members. This expansion results in an increase from eight to twelve research discipline teams. The four new teams are cross-cutting integrative research disciplines.

MEASURES OF PERFORMANCE

The actual data reported are based on interim information available as of mid-December 1999. Complete 1999 data will be available in February 2000 with publication of the 1999 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1999		FY 2000		FY 2001
	Plan	Actual (est.)	Plan	Revised	Plan
Number Principal Investigations	157	183	185	189	224
Number of Co-Investigators Supported	277	322	325	330	365
Number of Publications	285	332	335	343	375

ACCOMPLISHMENTS AND PLANS

FY 1999 included the flight of STS-95, a dedicated space shuttle research mission to conduct research in the life and microgravity sciences, including some exploratory research on aging and space flight. (A January 2000 symposium reported the preliminary results of STS 95.) OLMSA researchers also convened to conduct a one-year post-flight review of results from the Neurolab Space Shuttle mission. Preparations continued for STS-107, OLMSA's next major Space Shuttle flight opportunity, which will be dedicated to health and safety. Seven biomedical experiments have already been selected for STS-107. The BR& C released its annual NASA Research Announcement (NRA.) Genomic instability research continues to be jointly funded by the NASA space radiation health project and the National Cancer Institute. Construction of the Booster Applications Facility (BAF) at Brookhaven National Laboratory was started. In cooperation with Loma Linda University and Brookhaven National Laboratory, OLMSA researchers used the Loma Linda Proton Beam Facility and Brookhaven Heavy ion accelerators to simulate space radiation for radiation health research experiments. In FY 1999 Loma Linda University initiated development of a neurosciences research task. International collaboration in space radiation health involved 1) work with the Italian Space Agency to develop joint use of ground-based facilities, 2) participation by NASA investigators in research at the HIMAC facility of the National Institute of Radiological Sciences in Chiba, Japan, and 3) participation in the development of consensus recommendations to the Multilateral Medical Operation Panel for radiation protection on the ISS. An integrated Critical Path Research Plan was developed outlining a biomedical risk-based mitigation strategy for defining research requirements and selecting research to support future successful long-duration human space flights.

FY 2000 will include final preparations for initial research on the ISS. The Crew Health Care system and the first rack of the Human Research Facility will be deployed to the International Space Station and OLMSA will begin initial operations of these facilities. BR&C will release its annual NRA. Beginning in FY 2000 OLMSA is enlarging the role of the National Space Biomedical Research Institute (NSBRI) to strengthen countermeasure development and improve the safety and performance of flight crews. The Radiation Research Instrument for Mars 2001 mission to study transit, orbital, and surface radiation effects will be completed.

Additionally per Congressional direction in FY 2000, BR&C will provide $3.661M to the Space Radiation Program at California's Loma Linda University Hospital and $1.831M to the Neutron Therapy Facility at Fermilab in West Chicago, Illinois. Loma Linda has received directives of more than $20M in the past four years to develop the beam line and proton facility, outfit laboratory space and support staff positions. The FY 2000 directive funds facility operations, which includes support of OLMSA's space radiation health program. The Neutron Therapy Facility is an independent medical group located at Fermilab in Illinois. This directive provides initial funding to change and develop a technology transfer center to promote commercial uses for federal research technologies developed by NASA and DoE. OLMSA disclosed in the initial FY 2000 operating plan the funding from within the baseline BR&C program budget to be used towards the Booster Applications Facility (BAF) construction at Brookhaven National Laboratory. BAF was included in the summer update to the FY 1999 operating plan. The BAF will provide the capability to simulate all major ion components and energies of galactic cosmic rays and solar proton events. Once the BAF becomes operational, Brookhaven National Laboratory will provide NASA access to more that 2,000 beam-hours –per year in order to meet all of the goals of the NASA Strategic Radiation Health Plan.

In FY 2001, OLMSA will continue to expand research operations on the ISS. The Office is preparing a wide range of experiments for flight on the International Space Station in FY 2001 and developing an expanded research program to take full advantage of growing ISS capabilities in the future. Facilities for human research and the Microgravity Science Glove Box will be available to support this research as part of the continuing deployment of the ISS. OLMSA has plans to participate in the Mars Surveyor Program 2001 orbiter and lander missions and the Mars 2003 mission. Specific details of planned participation may be revised, pending the outcome of Mars planning reviews by the Office of Space Science. The BR & C program will release its annual NRA. Also, the Booster Application Facility (BAF) construction progresses towards completion for operational research beginning in FY 2002.

BASIS OF FY 2001 FUNDING REQUIREMENT

FUNDAMENTAL BIOLOGY

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Fundamental Biology (FB) (Formerly Gravitational Biology and Ecology (GB&E))	40,900	38,200	39,200

GOALS

The goals of Fundamental Biology are to: (1) determine the mechanisms by which the evolution, development, structure, and function of cells, physiological systems, organisms and ecosystems sense and respond to gravity; (2) develop knowledge to support human space flight via countermeasures and bioregenerative life support systems; and (3) transfer biological knowledge and technology gained through research on the ground and in space to the medical and scientific communities.

STRATEGY FOR ACHIEVING GOALS

Investments in Fundamental Biology will improve understanding of the role of gravity in biological processes by using a variety of gravitational environments as research tools or by determining the combined effects of gravity and other environmental factors on biological systems. The emphasis is on research in cell and molecular biology, evolutionary and developmental biology, and organismal and comparative biology. Its research includes plants, animals, or other organisms as subjects, as well as cell or tissue cultures. The disciplines supported are Physical Interactions, Cellular and Molecular Biology, Evolutionary Biology, Developmental Biology, Plant and Comparative Biology, Global Monitoring and Disease Prediction, Gravitational Ecology and other outreach activities.

Center Support

ARC is the Lead Center for implementing the Fundamental Biology (FB) program, with other centers used to administer tasks or for their unique expertise. KSC provides pre- and post-flight support for FB flight experiments. A key collaborative venture between NASA and the National Institutes of Allergy and Infections Diseases is the use of remote sensing technologies for the prediction and control of global vector-borne human disease.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1999. Complete 1999 data will be available in February 2000 with publication of the 1999 Annual Report or the OLMSA Life Sciences and Microgravity Research Program Tasks and Bibliographies.

	FY 1999		FY 2000		FY 2001
	Plan	Actual (est.)	Plan	Revised	Plan
Number of Principal Investigations	153	171	157	166	164
Number of Co-Investigators Supported	175	176	180	181	177
Number of Publications	300	318	310	320	317

ACCOMPLISHMENTS AND PLANS

During FY 1999, efforts to restructure and expand the scope of FB consistent with the NASA and HEDS strategic plans continued. This included the initiation of a program name change request from Gravitational Biology and Ecology (GB&E) to Fundamental Biology (FB). New research proposals were awarded. An integrated research activity in evolutionary biology was begun and investigations selected and awarded. Data from Neurolab flight experiments to define the time course of adaptations in the balance system to altered gravitational environments and to compare the responses of at least three different biological models to understand the influence of gravity on the normal development of the nervous system were analyzed and published. Data from research carried out on MIR were analyzed and the research results will allow a one year "jump start" for ISS fundamental biology in the area of plant biology.

During FY 2000, FB flight experiments will provide information on the effects of exposure to microgravity on plant growth and development, and information to determine the effects of gravity on plant photosynthesis and respiration. Flight experiments on the effects of microgravity on avian development will be initiated. The FB program office will release its annual NRA. Collaborative efforts are also funded in the Space Sciences program under the Astrobiology program.

During FY 2001, funding for FB will enable expansion of support to approximately 164 investigations. Published abstracts and reports of progress for over 90% of FY 2000 research investigations (tasks) will be publicly available on the Internet. A wider range of investigations in fundamental biology will be supported. FB will increase fundamental knowledge in biological and biomedical sciences and address critical questions in crew health and safety by conducting 6 to 10 ISS investigations. These will include continued investigations on the effects of gravity on plant growth and physiology, providing information on the effect of the space environment on bacterial virulence and providing information on the effect of microgravity on skeletal myofibers. Fundamental biology research will also be conducted on the STS-107 Research Module mission, including studies of cells, plants, and rats.

BASIS OF FY 2001 FUNDING REQUIREMENT

MICROGRAVITY RESEARCH

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Microgravity Research (MR)	113,700	108,800	129,260

GOALS

Microgravity Research (MR) seeks to use the microgravity environment of space as a tool to advance knowledge, to use space as a laboratory, to explore the physical foundations of natural processes, contributing to progress in science and technology on Earth; and to study the role of gravity in technological processes, building a scientific understanding of the consequences of gravitational environments beyond Earth's boundaries.

STRATEGY FOR ACHIEVING GOALS

The MR strategy for achieving these goals includes: sustaining leading-edge research focused in the areas of biotechnology, combustion science, fluid physics, fundamental physics, and materials science that effectively engages the national research community; fostering an interdisciplinary community to promote synergy, creativity and value in carrying out the research; enabling research through the development of an appropriate infrastructure of ground-based facilities, diagnostic capabilities and flight facilities/opportunities; promoting the exchange of scientific knowledge and technological advances among academic, governmental and industrial communities and disseminating the results to the general public and to educational institutions; raising the awareness of the microgravity research community regarding the long-term direction of the Human Exploration and Development of Space (HEDS) enterprise; and discussing with the community the role of microgravity research in support to agency objectives. Finally, MR will continue to support the NASA/National Cancer Institute (NCI) collaborative program to define the opportunities and research directions to advance the development of technologies and informational tools needed to enable minimally-invasive detection, diagnosis, and management of disease and injury. MR will contribute to the Bioastronautics Initiative with continued support to the NASA/NCI collaboration activities and will identify and improve spacecraft environment, habitability and crew health.

CENTER SUPPORT

MSFC is the Lead Center for MR, delegating management of specific science disciplines and associated hardware development to GRC, JPL, JSC, and MSFC. All Centers provide pre- and post-flight support for MR flight experiments. The National Center for Microgravity Research on Fluids and Combustion, a joint cooperative agreement between the Universities Space Research

Association, Case Western Reserve University and GRC, leads a national effort to increase both the number and quality of researchers and to accomplish integrated, critical path research in microgravity fluids and combustion sciences. New National Centers for Microgravity Research in Materials Science, and Fundamental Physics are in the formulation phase with authority to proceed with the issuance of announcements of opportunity in FY 2000.

SCHEDULE AND OUTPUTS

The actual data reported is based on interim information available as of mid-December 1999. Complete1999 data will be available in February 2000 with publication of the 1999 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1999		FY 2000		FY 2001	
	Plan	Actual (est.)	Plan	Revised	Plan	Revised
Number of Principal Investigations	344	472	543	546	514	480
Number of Co-Investigators Supported	395	540	600	600	560	530
Number of Publications	1420	1950	2140	2140	2000	1900

ACCOMPLISHMENTS AND PLANS

During FY 1999, Microgravity Research (MR) funding provided for the conduct of broad, productive Earth-based and space-based research. Based on research from the STS-90 mission, new genes were expressed for the first time under microgravity conditions in the Bioreactor. This research reveals that the microgravity environment of space fundamentally affects cellular processes and alters gene expression. It also represents the first application of recently developed gene array techniques to understand changes in cellular function in space. Exciting fundamental research results from fluid physics colloids experiments were obtained on STS-95. The Colloidal Gelation Experiment yielded insight into the formation of gels, a near rigid network of particles. This work is the essential first step in the synthesis of new materials from colloidal particles. The Colloidal Order-Disorder Transition Experiment yielded insight into the physics of the structure of materials at the atomic scale. Colloid systems are used to macroscopically model particle interactions at the atomic level.

Spacecraft Fire Safety data were verified through cooperative US/Russian MIR experiments. The flammability of selected U.S.-supplied plastic materials was tested under microgravity conditions in a Russian combustion tunnel operated on the *Mir* Orbital Station. The data was compared to reference testing of the flammability, heat release, thermal properties, and combustion products of identical materials in ground laboratories at both the Russian Keldysh Research Center and the NASA JSC White Sands Test Facility. Spacecraft radiation safety was advanced with an understanding of the fundamental processes and appropriate materials associated with shielding of spacecraft from space radiation. Progress includes development of a transport computer modeling code and of a nuclear database for evaluation of spacecraft shielding. This database consists of 75 important materials which are under characterization according to their shielding properties. An understanding of the production of neutrons due to collisions with spacecraft shielding materials has also been developed.

Optical particle manipulation techniques developed for colloids research, called laser tweezers and scissors, are being applied to In-vitro Fertilization Research at University Hospitals in Cleveland, OH. Interest in using the tweezers as a non-contact method for manipulating gametes and embryos in the laboratory prompted the collaboration. In addition, cell fusion studies using laser tweezers and scissors, may be performed by bringing two cells into contact and ablating the cell wall where they touch. Based on the early feasibility studies in the relevant fields, the collaboration is initially focusing on fusion studies.

Technology research in fundamental physics with the Magneto Optical Trap feasibility ground demonstration was successfully completed. This technology will enable significant increases in the accuracy of timekeeping and more generally enable a broad range of general relativity experiments utilizing the microgravity environment. The technology has been baselined for upcoming Fundamental Physics research on the ISS.

The program's continuing focus on communicating and interacting with the industrial sector resulted in receipt of initial recommendations from an Industrial Liaison Board, formed through an initiative of the National Center for Microgravity Research on Fluids and Combustion (NCMR), and convened by Dr. William Ballhaus, Vice President of Lockheed Martin Corporation. The board made recommendations on how NASA could enhance the value of its research on Microgravity Fluids and Combustion Research to the industrial sector.

In FY 1999, MR funding supported seven exploratory investigations in biology-inspired research. These investigations are the genesis of a research topic that will open new areas of technological development having tremendous impact on the efficient exploration of the near-Earth environment using the International Space Station, support future human exploration of space, and have a beneficial effect on the quality of life on Earth. This biology-inspired research involves smaller systems or machines with lower power requirements and much greater capability.

In FY 2000, MR funding is being used to continue preparation of upcoming ISS flight research, perform focused research activities on the STS-107 Research Mission, and conduct three investigations using suborbital rockets. Initial research deployment of Protein Crystal Growth experiments will begin on ISS on Flight 4A in the second half of CY 2000. Continued development of the ISS Fluid and Combustion Facility and Materials Science Research Facility will occur with Critical Design Reviews being conducted. Research needed to generate low-gravity technology required to advance human exploration of the solar system will be expanded. New research investigations will be selected in materials science in preparation for the deployment of major and sophisticated research apparatus aboard the ISS.

The mission integration and science program functions for the Alpha Magnetic Spectrometer (AMS) experiments are provided for as part of NASA's efforts in Fundamental Physics. This investigation is a collaboration of NASA and the Department of energy, and represents an international effort led by Nobel laureate Professor S.Ting to perform accurate and long-duration measurements of energetic cosmic rays spectra in search of dark matter, utilizing the International Space Station.

MR funding provides for continued support of exploratory research in biology-inspired technologies, including issuance of a cooperative agreement notice for a virtual center in advanced biotechnology. This center will tie together the research results and provide broader distribution of results from this biologically-inspired research.

In FY 2001, MR funding will provide for continued development preparations for upcoming ISS flight research, focused research activities on the STS-107 Research Mission, and conduct of three investigations using suborbital rockets. Research deployment aboard the ISS will increase with six flights occurring, setting the stage for future full utilization. MR will deliver thirty-three payloads in FY 2001. The payloads will support research investigations in the areas of biotechnology (macromolecular and cell science), materials science, fluid physics, and acceleration measurement. Research needed to generate low-gravity technology required to advance human exploration of the solar system will continue expand and evolve. New research projects will be selected in Combustion Science and Fundamental Physics. Early ISS utilization will expand with science investigations being conducted on the Microgravity Science Glovebox and Express Rack. An increasing number of investigations will be undergoing final engineering readiness reviews in preparation for deployment in the ISS science research facilities.

Additionally in FY 2001, MR funding will support the development of a second generation research announcement in biology-inspired technologies with the idea of bringing some of the more promising technologies to a point of maturity where they could be used to support NASA missions. The potential areas are the following: 1) extending the capabilities of human interactions with machines through enhanced computational capabilities or improved sensor and data-handling capabilities, and 2) use of new biological materials or structural concepts inspired by biological functions found in nature.

MR will support a NASA/NCI collaborative program to define the opportunities and research directions to advance the development of technologies and informatics tools needed to enable minimally-invasive detection, diagnosis, and management of disease and injury. The technological breakthroughs in these areas will enable the development of revolutionary systems needed to support common and unique objectives of NASA and NCI including medical monitoring and management, early disease detection and intervention, and scientific exploration on Earth and in space. In FY 2001, MR funding provides for management oversight of the DOE sponsored AMS mission including the Critical Design Review (CDR) and the first NASA integration hardware deliveries to the DOE/AMS payload developer. In FY 1999, management oversight of the AMS mission was funded under the Mission Integration program.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE PRODUCT DEVELOPMENT

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Space Product Development (SPD)	15,400	14,400	13,600

GOALS

The Space Product Development (SPD) Program facilitates the use of space for development of commercial products and services (including appropriate supporting ground-based activities); couples NASA and private sector technology development to the advantage of both; and incubates commercial enterprises that use space on a profit-making basis. The SPD Program also promotes the benefits of space-based research to industry, facilities industry's access to space, provides space research expertise and flight hardware, and advocates the development of policies to encourage commercial use of space.

STRATEGY FOR ACHIEVING GOALS

This program supports the operation of the NASA Commercial Space Centers (CSC), commercial flight research hardware for Shuttle and provides parabolic aircraft flight opportunity and program support to hardware funded by the Space Station office and developed for the International Space Station. The CSCs are partnerships of industry, universities, and local, state, and other federal agencies engaged in commercial space research. SPD encompasses a broad range of NASA efforts to encourage industry participation and investment in space. Commercial space research has the potential to create new or improved products, create jobs, give U.S. industry competitive advantages and improve the quality of life on Earth.

Center Support

The SPD program is managed by the Microgravity Research (MR) Program Office at the MSFC. The SPD program is primarily implemented through CSCs. Each CSC is a non-profit consortium of commercial and academic entities. Some also have government agency participation. The CSCs follow business leads and commitments to pursue product-oriented research in three major disciplines: materials research and development, biotechnology, and agriculture. NASA's role in this partnership is to provide leadership and direction for the integrated program and to provide the flight opportunities that are essential to the success of these efforts.

During FY 1999, in response to National Academy of Public Administration (NAPA) recommendations, the most promising of commercial research projects directly managed by the Space Product Development program at the Marshall Space Flight Center,

were identified for possible transition to Commercial Space Centers. The long-term objective is to foster a more direct link between research planning and the private sector's investment in that research. The Space Product Development team plans to complete the transition of NASA commercial projects to the Commercial Space Center in FY 2000.

The CSCs have a unique role in assisting private businesses to conduct space research. They demonstrate to industry the values of space research, and they provide expertise essential to the conduct of successful research in space. CSCs furnish an infrastructure that provides a cost-effective and efficient way for companies to conduct research in space. The CSCs initiate industry involvement: first, by identifying and investigating industry-led research areas of commercial promise; and, second, by assessing markets for these potential research opportunities. The businesses support the research effort with resources including cash and in-kind, such as technical expertise, research materials, personnel, ground facilities, and research hardware.
Throughout much of the past decade, the CSCs have been active research participants in Shuttle flight activity and have optimized their research opportunities. Building on research results from Shuttle missions, the CSCs are expanding their research goals and evolving hardware experiment infrastructure to take full advantage of the extended microgravity environment the International Space Station will offer.

MEASURES OF PERFORMANCE

The measures of performance for SPD program include the number of university and industry affiliates that are working with NASA in the commercialization of space and the amount of funding leveraged from non-NASA sources by the CSCs.

	FY 1999		FY 2000		FY2001
	Plan	Actual	Plan	Revised	Plan
Industry Affiliates	145	159	162	155	170
University Affiliates	68	68	80	74	80
Payloads Flown (Shuttle)	11	10	12	2	6
(ISS)	--	--	-	-	7
Non-NASA $M Leveraged	55M	51.2M	60.0M	51.2M	52M

ACCOMPLISHMENTS AND PLANS

In FY 1999, significant commercial research activity was conducted on Shuttle missions including STS -95 in October, 1998 and STS -93 in July, 1999. On STS 95 there were eight commercial research payloads: Aerogel, Commercial Generic Bioprocessing Apparatus (CGBA), BioDyn, Astroculture,™, Commercial ITA Biomedical Experiment (CIBX), Advanced Separation (ADSEP), Commercial Protein Crystal Growth, and Microencapsulation Electrostatic Processing, with multiple experiment activities on several of the eight payloads noted. Substantial commercial research gains were achieved including the following:

- Antibiotic Production: BioServe Space Technologies, a NASA Commercial Space Center, and their industry partner, Bristol-Myers Squibb, used the CGBA apparatus to conduct research on the production of microorganisms of the antibiotic actinomycin D, used in conjunction with cancer treatments. BioServe and their industry partner achieved a 75% higher rate over comparable ground control experiments, providing new insights that may improve ground-based production of antibiotics and therefore reduce the cost of antibiotic development.

- Insulin Research: The Center for Macromolecular Crystallography, a NASA Commercial Space Center, in collaboration with The Hauptman Research Institute, grew large crystals of human insulin which yielded high quality data allowing the electrostatic (as opposed to geometric) structure to be determined. This science will be extremely useful in the development of improved insulin formulations for the treatment of diabetes.

In addition to commercial research advances through flight activity, several ground-based research efforts also met with success.

- Imaging Technology: The Center for Commercial Applications of Combustion in Space, a NASA Commercial Space Center, developed two specialized cameras for combustion research. The Center, along with its industry partner, Roper Scientific, are now marketing these cameras in the medical imaging field. This new technology will allow weak images to be pulled from strong backgrounds, such as when tumors have the same general color and lighting as surrounding tissues.

- Telemedicine Demonstration: Physicians and scientists from Yale University, in association with the Medical Informatics and Technology Applications Center, a NASA-funded activity, accompanied professional climbers on an expedition to Mt. Everest where they evaluated emerging technologies in medical monitoring that have substantial application for diagnostic purposes in human space flight. This is an essential ingredient for long-duration space missions, and for remote location diagnostic applications on Earth, such as disaster relief efforts and remote location health care.

In FY 1999 the Space Product Development office at NASA's Marshall Space Flight Center strengthened its program oversight and assessment capabilities through the addition of several new program managers. They are an important asset, augmenting the small but experienced Space Product Development staff already in place.

Also in FY 1999, NASA program managers in the Space Utilization and Product Development office worked with NASA's Office of General Counsel to release a document that provided guidance on intellectual property and the International Space Station:

creation, use, transfer, ownership and protection. This document will be used to brief prospective commercial users of the International Space Station on the regulations governing intellectual property aspects of research associated with the International Space Station.

Throughout FY 2000, the Space Product Development office will continue support for commercial research in biotechnology, agriculture and materials processing. Several commercial payloads in the fields of materials research, protein crystal growth, and agriculture will undergo program and technical assessments in preparation for flight on STS 107, the next substantial opportunity for commercial space research. Commercial research hardware infrastructure development will continue for deployment in the upcoming ISS Utilization flights. The Medical Informatics Technology Applications Center, located in Virginia Commonwealth University, will foster the establishment of a telemedicine hub in Western Europe. NASA will also target at least 30% of available Space Shuttle and ISS research capabilities for commercial researchers, per the U.S. Payload Utilization Planning guidelines.

During FY 2001, Space Product Development will have as its goal the expansion of commitment from the private sector to invest in commercial space, as evidenced by at least ten new, active industry partners to the Commercial Space Centers. There are presently 159 commercial affiliates associated with 10 Commercial Space Centers. NASA will continue to be proactive in the development of policies and plans that foster commercial endeavors. As access to space is a key factor in obtaining and maintaining commercial sector commitment to and investment in space for product research, Space Product Development will support planning and preparation for commercial space product research on the ISS and on Shuttle for flight opportunities as they become available.

BASIS OF FY 2001 FUNDING REQUIREMENT

HEALTH RESEARCH

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Health Research (HR)	[7,600]	[8,700]	11,300
Occupational Health Research (OHR)	[900]	[1,400]	[1,100]
Space Medicine Research (SMR)	[6,700]	[7,300]	[10,200]

Commencing in FY 2001, the previously separate Occupational Health Research and Space Medicine Research functional activities have been combined into one single budget structure entitled Health Research. The combination of Space Medical Research and Occupational health Research into Health Research focuses the Agency's health research and health care functions for its workforce under one program, the Office of Health Affairs, OLMSA. Research conducted under the revised program is expected to have potential applicability for both general employee health and the health of astronauts during space flight. For purposes of transition, provided below is the budget content described in the prior budget structure.

GOALS (OCCUPATIONAL HEALTH RESEARCH)

The goals of the Health Research program include 1) Under Occupational Health Research, to improve NASA's Occupational Health program effectiveness and efficiency.; and 2) that NASA complies with all Federal safety and health requirements.

STRATEGY FOR ACHIEVING GOALS

OHR funding provides for policy formulation and oversight of NASA-wide occupational and environmental health programs. The OHR function consists of several well-defined constituent activities including Occupational Medicine, Industrial Hygiene, Radiation Health, Physical Fitness, Employee Assistance Programs, Workers' Compensation, Nutrition and Food Safety, and Wellness and Health Education. Collectively, these constituent activities assure the well-being and productivity of the NASA work force. OHR has the primary responsibility for the control and elimination of harmful exposures of NASA employees to toxic chemicals and hazardous physical agents, for the prevention of occupational disease and injury, and the promotion of optimal health, performance and productivity. KSC is the Principal Center for OHR. Primary strategic elements include: annual program planning, comprehensive audits of occupational health programs throughout NASA, consolidation of services such as technical support and training program development, metric definition and compilation, program status reporting to NASA Senior Management, program standardization and automation; increased inter-center communication; quality assurance programs including clinic accreditation through the Joint Commission on Accreditation of Health Care Organizations and the Occupational Safety and Health Administration Voluntary

Protection Program; technical support center augmentation; and a training program development. Health Research will be an integral discipline of the Bioastronautics Initiative providing advanced medical systems and health care system validation.

MEASURES OF PERFORMANCE

Agency Workers' Compensation Rates	Reduce the incidence of harmful stress in the workplace by developing and implementing supervisor-specific training for the identification and management of stress in the workunit. Develop and implement training on techniques for coping with stress for the individual employee.
Agency Wellness programs	Begin a robust audit program of NASA Centers' occupational health programs, completing at least six (6) to ensure quality and continuous improvement of medical care and services including medical and environmental monitoring efforts, preventive services, emergency response capability, stress management efforts, and clinical intervention capability.

ACCOMPLISHMENTS AND PLANS

During FY 1999 OHR conducted two series of continuing education video-conferencing seminars on Bioethics and Health Surveillance and Maintenance in the Workplace and broadcast them to the Institute of Biomedical Problems in Moscow, the Commercial Center for Medical Informatics and Technology at Virginia Commonwealth University, other select academic institutions within the U.S., and all NASA centers. The benchmarking of OHR activities was expanded to include world class private industry organizations, selected through the American Productivity and Quality Control (APQC). A streamlined process verification of Center OHR activities was implemented. Formal collaborations with the Center for Disease Control and Prevention (CDC) and the American Heart Association were investigated for potential collaborative use of the HERO database and development of an outcomes-based Health Risk Appraisal instrument. An Occupational Health technical support center was established. An on-line support network of Agency resources on critical occupational health issues was implemented. Development of web site training modules for Employee Assistance topics was initiated with a module for all supervisors. Inter-agency agreements were continued to effect cost savings and to deliver specific subject matter expertise to all NASA Centers. NASA signed its initial agreements with the Joint Commission for the provision of clinic accreditation services.

During FY 2000, OHR will continue the series of professional education ViTS seminars starting with a series on Emerging Infectious Diseases. The series will be broadcast to the Medical Informatics and Technology Applications Consortium, Medical College of Virginia, the Institute of Biomedical Problems in Moscow, the European Institute of Telemedicine in Toulouse, France, other select academic institutions within the U.S., and all NASA centers. These series will also be available on the Internet for viewing on a desktop computer. A new comprehensive audit system is under development and will be deployed to 50% of the NASA locations each year. The Principal Center will complete a study to identify the feasibility of contract consolidation across the Centers. A pilot

study utilizing the National Depression Screening Project will be completed. A new contract for providing after-hours employee assistance program coverage to all NASA facilities will be implemented. Two key NASA sites will initiate clinic accreditation through JCAHO. New Agency level metrics on skin cancer prevention, wellness and early diagnosis and intervention in disease will be instituted.

During 2001, OHR will continue emphasis on quality assurance for its occupational health program through implementation of clinic accreditation, certification of safety and health programs under the Occupational Safety and Health Administration Voluntary Protection Program, continuing professional education series, internal auditing and possible contract consolidation. Emphasis will also be placed on teaming with other Federal agencies for the delivery of services in a cost-effective manner. Wherever subject matter expertise can be obtained through inter-agency agreements, those agreements will be effected. Existing programs for technical center operation, program auditing, program standardization, senior management program reporting and advocacy, regulatory agency liaison, and oversight of the NASA occupational health function will be continued.

GOALS (SPACE MEDICINE RESEARCH)

The goals of Space Medicine Research (SMR) are (1) to ensure the health, safety, and performance of space flight crew members on all U.S. missions: Space Shuttle, the ISS, and the exploration missions; and (2) define and establish the requirements for clinical care and medical research.

STRATEGY FOR ACHIEVING GOALS

Within SMR, there are five elements that need to be tightly integrated: mission support for the Shuttle and ISS Program; astronaut health care; epidemiology (longitudinal studies of astronaut health); Crew Health Monitoring and Risk Mitigation (CHMRM); and Clinical Care Capability Development Program (CCCDP). The policies and requirements are developed to maintain and provide medical support to optimize the health, safety and productivity of our astronauts in space. This also includes technology and application developments. SMR funding provides for guidance and oversight of the medical operational support for human space flight and astronaut health care. SMR's scope ranges from the development of astronaut health policies, standards, and requirements for medical operations and medical research as well as the implementation of these requirements through operational medical support for all human space flight programs.

Center Support

JSC is the Lead Center for SMR. JSC manages clinical medical and psychological support of the astronauts as well as telemedicine efforts in support of medical operations activities for the Human Space Flight (HSF) Program. The major participating academic institutions are Wright State University School of Medicine, Medical College of Virginia at the Virginia Commonwealth University, and the University of Texas Medical Branch at Galveston.

MEASURES OF PERFORMANCE

Crew Health Care System Plan: 2nd Qtr 00 Actual: 3rd Qtr 99	Develop protocols and test the capability of the CHeCS as integrated into the ISS.

ACCOMPLISHMENTS AND PLANS

During FY 1999, NASA contracted with the Joint Commission Resources (a consulting group formed to do the review for accreditation) to provide an analysis of the current state of NASA's Health Care Delivery System and what actions would be needed for the system to receive accreditation. In addition, the National Academy of Sciences (NAS), Institute of Medicine (IOM) began a two year study of what actions need to be taken for the Space Medicine Program to be able to fully support long duration human space missions in low Earth orbit and beyond. The CHMRM program was developed to provide and integrate health management: clinical services, medical monitoring, preventive countermeasures, and clinical medical research, to help ensure the health and safety of ISS crewmembers. CCCDP funding was used to evaluate and refine space flight medical requirements and procedures and to identify and develop technologies required for the delivery of inflight crew health care. CCCDP activities included evaluation of the Telemedicine Instrumentation Pack (TIP) on ground based missions in Montana and Texas, and the identification of technology development areas that will be key to delivery of effective medical care during long duration space flight. The Agency Strategic Plan for Telemedicine was implemented through partnerships with the NASA Centers and the Medical Informatics and Technology Applications Consortium (MITAC) at Virginia Commonwealth University. Epidemiology continued to examine the incidence of acute and chronic morbidity and mortality among astronauts to better define the medical risks associated with space flight.

During FY 2000, SMR funding provides continued support of the needs of the space medicine community for Shuttle missions including operational medical support for the ISS. CHMRM funding will assist in the development, monitoring and interpretation of operational health related data from space flight including: support of the implementation and interpretation of Medical Requirements (MRs) for STS and ISS, and IPT support of rapid responses to clinical studies relative to space medicine issues. ISS CHeCS components will be deployed early in the ISS assembly sequence to provide on-orbit medical, environmental, and countermeasure capabilities for all ISS crewmembers. CCCDP funding will support the ongoing evolution of space medicine requirements, procedures, and technologies. Plans will be developed to augment ISS CHeCS with new and emerging medical and environmental technologies, many of which will be in the process of development at the NSBRI. Epidemiological efforts will continue to evaluate the growing body of astronaut health data to better define the medical risks associated with space flight. Special emphasis will be placed on clinical medical research, radiation research and psychological/human factors.

During FY 2001, SMR funding will continue supporting the needs of the operational medicine community for Shuttle and ISS missions. Deliverables associated with the CHMRM will include Medical Assessment Tests (MATs), Medical Requirements Integration Documents (MRIDs) for each MR, clinical interpretation and reporting in collaboration with the crew flight surgeon, data delivery for archiving and later epidemiological evaluation, and health risk assessments as needed. Additional ISS CHeCS components will be utilized to provide on-orbit medical, environmental, and countermeasure capabilities for all ISS crew members. In-flight Shuttle and

ISS medical capabilities will be augmented with new flight-proven technologies. Medical and environmental information gained from continuing CHMRM will be utilized to refine medical flight system requirements, protocols, and procedures. CCCDP funding will provide impetus for the evolution of space medicine requirements, procedures, and technologies. Epidemiological efforts will continue to better define the human medical risks associated with space flight and the effectiveness of operational countermeasures in dealing with these risks. Special emphasis will continue in the areas of clinical medical practice, radiation and psychology/human factors.

BASIS OF FY 2001 FUNDING REQUIREMENT

MISSION INTEGRATION

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Mission Integration (MI)	1,700	17,214	240
(Life Sciences Research Facility)		[12,814]	

GOALS

The goals of Mission Integration (MI) are: (1) provide physical, analytical, and operations integration support for Human Space Flight missions, to achieve NASA mission objectives for the science and technology communities; and (2) ensure integrated scientific, technological, and commercial user advocacy and coordination of requirements for the next generation of space laboratories, the ISS. These activities include the integration, coordination and policy planning and analysis for International research activities within OLMSA.

STRATEGY FOR ACHIEVING GOALS

In order to meet the function goals and objectives, MI performs the space-based research utilization planning of all OLMSA Space Shuttle and ISS payloads. In addition, through this function, MI carries out systems engineering efforts to develop and evaluate strategies and processes for satisfying current and future research mission objectives. These tasks not only address the current human based space flight platform mission integration processes, but, based on this knowledge base, they define and support new effective and efficient processes and tools for carrying out integrated research advocacy, requirements coordination, mission planning and operations for future space platforms. In particular, the program is investigating ways to apply the engineering and operations lessons learned in the Spacelab program and the NASA/MIR Research Program (NMRP) to the ISS program to achieve greater efficiencies.

Center Support

Headquarters remains the Lead Center for planning and directing Mission Integration. The principal NASA Centers, which conduct activities in support of MI, are JSC, KSC, and MSFC. The JSC is the primary center for providing the mission implementation function for Headquarters research mission activities, and is responsible for monitoring the contract for SpaceHab Inc. the commercial carrier provider that has assumed the payload integration function post-Spacelab. SpaceHab provided payload

management and integration for research payloads on the STS-95 Research Module mission in FY 1999, and will perform a similar function for the STS-107 Research Module mission scheduled for launch in early 2nd quarter FY 2001.

MEASURES OF PERFORMANCE

The most significant measure of MI performance is the provision of an integrated system that ensures successful accomplishment of the science payload objectives on Space Shuttle missions that carry OLMSA sponsored research. Although not directly responsible for the success of a particular experiment, MI is intrinsic for ensuring that all necessary planning and integration of the collected set of instruments have been comprehensively completed and fully coordinated so that the experimental hardware in concert with flight crew performance and ground control direction have the opportunity to conduct the planned science activities. Science payload objectives vary considerably depending upon the type of mission supported (module missions, pallet/MPESS missions or Space Shuttle Middecks) and the type of scientific investigations performed (microgravity, life sciences, Earth and stellar observations). Depending upon the type of payload, performance is characteristically measured and reported in terms of the actual science/research accomplishment vis-à-vis planned accomplishment specified by the anticipated on-orbit crew activity timeline. Another useful metric involves publications in peer science journals. The data usually lags a flight by two to three years because of data analysis and publication review and/or edit times.

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Revised	Plan
SpaceHab/Pallet/Shuttle	1	1	1	--	1
Middecks/Small Payloads	4	6	--	5	--

ACCOMPLISHMENTS AND PLANS

During FY 1999, MI funding provided support for the completion of the STS-95 Research Module mission which flew Senator John Glenn. In addition, initial MI support was provided for defining a second research mission (STS-107) to provide a transition between the completed Shuttle research missions and the onset of significant research capability on-board the ISS. As with STS-95, this mission is intended to be a pathfinder for future commercial involvement in carrying out orbital research, and will be implemented through SpaceHab for the carrier and carrier integration services. This mission, which incorporates "lessons learned" from the STS-95 flight, is an Extended Duration Orbiter (EDO) (14-16 day) mission and is anticipated to fly in early 2nd quarter FY 2001. It is also the first flight of SpaceHab's Research Double Module (RDM), effectively doubling the upmass capacity for OLMSA related research compared to the prior STS-95 allocation. A proposed payload complement with thematic emphasis towards crew health and safety has been baselined. The manifest also includes several commercial-type small payloads. In FY 1999 the Alpha Magnetic Spectrometry (AMS) payload was used to conduct a post-flight assessment of the STS-91 mission, as well as initial planning for the next flight of AMS as an externally attached payload on the ISS.

Early in FY 1999 NASA examined plans for a "standby research mission", involving both new and reflown scientific research, which could be inserted into the Shuttle manifest if and when an ISS or Shuttle schedule anomaly occurred. However, this was shown to

be a non-viable mission alternative with poor return on investment for PIs, payload equipment developers, and commercial payloads, because of the high cost of being in standby mode over a potentially long period of time.

During FY 2000, MI will continue support for the second DOE-sponsored Alpha Magnetic Spectrometry (AMS) mission planned for the ISS including the Preliminary Design Review (PDR) for integration on ISS and the initial safety reviews. Continuing Space Shuttle "pathfinder" research missions such as STS-107 will provide space access to the science and commercial programs until a substantive research capability is available on the ISS. To offset some of the costs, SpaceHab again (similar to STS-95) has been allocated some of the carrier capability to market to non-NASA customers, including ISS partners who wish to take advantage of this research opportunity before they have access to ISS utilization.

Additionally, per Congressional direction in FY 2000, MI will supply funding of $12.814M for construction of a life sciences research facility at the University of Missouri, Columbia.

In FY 2001, MI will transfer management oversight in support for the DOE-sponsored AMS mission including the Critical Design Review (CDR) and the first NASA integration hardware deliveries to the DOE/AMS payload developer to Microgravity Research. The first Research Double Module (RDM) will be flown on STS-107. In the interim, science/research at the middeck locker equivalent (MLE) level will be flown on ISS assembly flights on a space-available basis.

P.L. 106-74 includes a limitation stipulating that $40 million of the amount provided for Human Space Flight "shall be available to the space shuttle program only for preparations necessary to carry out a life and micro-gravity science mission, to be flown between STS-107 and December 2001." The amounts earmarked within the FY 2000 Shuttle budget ($40 million) and amounts available in FY 1999 appropriations for Life and Microgravity Sciences and Applications ($10 million) fall considerably short of the funds needed to conduct a science mission, which ranges from about $137-166 million. A page on this issue is in the Special Issue Section.

BASIS OF FY 2001 FUNDING REQUIREMENT

INVESTMENTS

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Investments (MURED)	[1,000]	[1,000]	1,000

The Human Exploration and Development of Space (HEDS) Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating HEDS Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U. S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the HEDS Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

EARTH SCIENCE BUDGET STRUCTURE CHANGE

NASA has restructured the Earth Science Budget in FY 2001 to display the resources being allocated to Research and Technology requirements in a way that can be more readily understood by NASA's customers. As a result, the Research and Technology requirements have been allocated into three categories: Earth Science Program Science, Applications Commercialization and Education (ACE) and Technology Infusion. This restructured format aligns the Research and Technology requirements with the way that they are managed within the Agency.

Given the complexity of the restructure, NASA has elected to cast the entire Earth Science Budget Narrative in the New Structure. A crosswalk from the Old Structure to the New Structure by Fiscal Year is provided in the Special Issues Section.

The following table summarizes the a Old Structure for FY 1999/FY 2000 and New Structure for FY 2001:

SCIENCE, AERONAUTICS, AND TECHNOLOGY	FY 1999 OLD STRUCTURE	FY 2000 OLD STRUCTURE	FY 2001 NEW STRUCTURE
OFFICE OF EARTH SCIENCE	**1413.8**	**1443.4**	**1405.8**
Major Development (New Structure)			
EOS	**632.4**	**575.4**	**447.1**
Terra	31.8	6.2	3.1
Aqua	113.1	92.8	42.9
Chem	132.8	124.7	110.3
Special	116.0	120.4	86.7
QuikScat	11.4	1.1	
Landsat-7	17.0	9.6	1.4
Algorithm Development	116.8	121.7	82.1
EOS Follow-on	4.5	24.4	120.6
Technology Infusion	89.0	74.5	
NMP	56.1	37.1	
Advanced Info Systems Tech	6.5	12.5	
Sensor and Detector (now titled Adv Tech Initiative)	5.5	9.9	
Instrument Incubator	20.9	15.0	
EOSDIS	**261.7**	**261.9**	**252.0**
Earth Probes	**109.3**	**157.4**	**120.4**
TOMS	9.9	24.8	0.5
UnESS		2.0	11.5
ESSP	62.3	94.5	105.9
LightSAR		0.0	
Triana	35.0	35.1	2.0
Experiments of Opportunity	2.1	1.0	0.5
Research and Technology (New Structure)			
Applied Research and Data Analysis	**399.7**	**436.5**	**533.3**
Science/Earth Science Program Science	323.6	359.4	353.2
Airborne	18.1	22.1	22.7
UAV Science	1.9	4.0	5.0
Commercial Remote Sensing	38.1	30.4	
Mission Science Teams	48.1	55.8	100.0
R&A (included education and outreach)			

SCIENCE, AERONAUTICS, AND TECHNOLOGY	FY 1999 OLD STRUCTURE	FY 2000 OLD STRUCTURE	FY 2001 NEW STRUCTURE
EOS Science	46.4	60.3	52.2
R&A	161.6	174.6	
R&A - Research			163.6
Education	9.4	12.2	
Infor Systems			9.7
Applications Commercialization and Education			69.2
R&A - Applications			21.2
Commercial Remote Sensing			31.9
Education and Outreach			16.1
Education and Outreach			4.1
EOS Fellowships			7.0
GLOBE			5.0
Technology Infusion			110.9
NMP			50.1
Adv Infor Systems Tech			14.0
Adv Technology Initiatives			10.0
Instrument Incubator			15.0
HPCC			21.8
Operations (New Structure)			**42.7**
Investments (New Structure)			**10.3**
Operations, Data Retrieval, and Storage	76.1	77.1	
Mission Operations	55.5	47.6	
HPCC	14.5	21.9	
Info Systems	6.1	7.6	
GLOBE	**5.0**	**5.0**	
Launch Services	**4.2**		
SRTM		**6.2**	**0.0**
CofF	**1.5**	**1.0**	**0.0**

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE

OLD STRUCTURE

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Earth Observing System	632,400	575,415
Earth Observing System Data Information System	261,700	261,906
Earth Probes	109,300	157,400
Applied Research and Data Analysis	399,700	436,504
Earth Science Program Science	323,600	359,404
Operations, Data Retrieval and Storage	76,100	77,100
Global Observations to Benefit the Environment	5,000	5,000
Launch Services	4,200	--
Construction of Facilities	1,500	1,000
Shuttle Radar Topography Mission	--	6,200
Total	1,413,800	1,443,425

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE **EARTH SCIENCE**

PROPOSED NEW STRUCTURE

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	PAGE NUMBER
		(Thousands of Dollars)		
Major Development	[918,600]	[926,406]	819,500	
Earth Observing System	[547,600]	[500,900]	447,100	SAT 3-14
Earth Observing System Data Information System	[261,700]	[261,906]	252,000	SAT 3-29
Earth Probes (Includes SRTM)	[109,300]	[163,600]	120,400	SAT 3-36
Research and Technology	[439,700]	[469,419]	533,300	SAT 3-43
Earth Science Program Science	[251,800]	[286,300]	353,200	SAT 3-45
*Applications, Commercialization and Education	[82,900]	[85,704]	69,200	SAT 3-66
Technology Infusion	[103,500]	[96,415]	110,900	SAT 3-77
Construction of Facilities	[1,500]	[1,000]	--	SAT 3-84
Mission Operations	[55,500]	[47,600]	42,700	SAT 3-85
Investments (included in ACE in FY99-00)			10,300	SAT 3-90
Minority University Research & Education Program			8,800	
Education			1,500	
Total with Investment	[1,413,800]	[1,443,425]	1,405,800	

Distribution of Program Amount by Installation	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
Johnson Space Center	5,520	5,005	4,595
Kennedy Space Center	65,584	73,044	88,005
Marshall Space Flight Center	30,141	35,550	37,593
Stennis Space Center	39,491	32,845	36,290
Ames Research Center	15,868	17,394	15,239
Dryden Flight Research Center	16,432	20,500	20,450
Langley Research Center	74,073	87,047	101,667
Goddard Space Flight Center	882,418	895,380	811,984
Jet Propulsion Laboratory	247,300	248,174	248,492
Headquarters	36,973	28,486	41,485
Total	1,413,800	1,443,425	1,405,800

* Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. GLOBE after FY00 has been included under the ACE program. Detail of this content is provided in the narrative below.

EARTH SCIENCE ENTERPRISE

PROGRAM GOALS

The purpose of NASA's Earth Science Enterprise (ESE) is to observe the global Earth environment, to understand the mechanisms that underlie natural and human-induced environmental changes, and to identify consequences that could impact human societies. In short, the purpose of the Enterprise is to provide scientific answers to the fundamental question:

How is the Earth changing, and what are the consequences for human civilization?

A fundamental discovery made during the 20th century is the existence of a multiplicity of linkages between diverse natural phenomena and interactions between the individual components of the Earth system. As a result, a new "Earth system science" concept developed, with the aim of investigating the complex behavior of the total Earth environment in which the global atmosphere, the oceans, the solid Earth and ice-covered regions of the Earth, and the biosphere all function as a single interactive system. Earth system science is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. ESE has established three broad goals. They are to 1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and *in situ* platforms; 2) disseminate information about the Earth system; and 3) enable productive use of Earth science program science and technology in the public and private sectors.

NASA has long been pursuing a vision of an interdisciplinary Earth system science. Traditional scientific disciplines have already progressed a long way in the study of the atmosphere, biosphere, land, and oceans as quasi-independent components of a stationary Earth system, while treating the interfaces between components as prescribed boundary conditions. Building on these scientific achievements, the strategy of Earth system science is to promote a "coordinated [research] effort between adjacent scientific disciplines and observation programs focused on common interrelated problems that affect the Earth as a whole" (*Toward an International Biosphere-Geosphere Program*; National Research Council (NRC), 1983). The ultimate goal of the NASA Earth Science Enterprise is to achieve this synthesis and understand the interactive physical, chemical and biological processes that govern the total Earth system. With this knowledge, NASA and its partners will develop prediction capabilities to quantify the effects of natural and human-induced changes on the global environment. Operational agencies such as National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS), who are partners in this effort, can use these capabilities to improve weather and climate forecasting, natural resource management, and other services on which the Nation relies.

STRATEGY FOR ACHIEVING GOALS

The first Earth Science Research Plan, published in 1996, laid out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use changes; short-term climate events, natural hazards research and applications; long-term climate change research; and atmospheric ozone research. The plan also outlined some twenty related areas of research, which round out the Earth science contribution to Earth system science. NRC recognized the complexity of global Earth environment issues, the multiplicity of interactions between component processes and the cross-disciplinary connections they evoke (*Research Pathways for the Next Decade-Overview*; NRC, 1998). In the face of such complexity, the NRC outlined a diversity of unsolved scientific questions that call for further study, but also emphasized the need for a focused scientific strategy, concentrating efforts and resources on critical scientific problems that are most relevant to national policy issues. Responding to the latter recommendation, the ESE is developing a targeted research program, focused on an updated set of specific science questions that can be addressed effectively with NASA's capabilities, and formulating comprehensive research strategies that can lead to definitive scientific answers, as well as effective applications of those scientific results.

The key research topics studied by NASA's Earth Science Enterprise fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth science program, although it is particularly relevant to the problem of climate change, a major Earth science-related issues facing the countries of the world. The Earth Science Enterprise has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering.

- *How does the Earth change naturally?*
- *What are the primary forcings of the Earth system by human activities?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of changes in the earth system for human civilization?*
- *How can we predict the changes in the Earth system that will take place in the future?*

NASA expects that expanded scientific knowledge of Earth processes and the utilization of advanced space-based and airborne observing techniques or facilities developed by NASA will result in practical applications beneficial to all citizens. Examples of these applications may include the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; quantitative weather and hydrologic forecasts over an extended range of one to two weeks; prediction of seasonal or longer-range climate variations, global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. NASA's Earth science research program comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, Federal, State, and local government use this knowledge to produce products and services essential to achieving sustainable development. Enabling us to get at the answers to the science questions, our top priority continues to be our existing near term commitments with the launch of our first series of EOS and selected Earth probe missions that are nearing completion. In addition, we are committed to deliver a functioning data and information system to support the processing, archival and distribution of data

products for these missions. These satellites will propel the Enterprise into a new era of data collection, research and analysis for which both the national and international Earth science community has been preparing over the last decade.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua (formerly PM), Chemistry, Landsat 7 Jason 1, ICEsat, ACRIMSAT and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches began in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions that are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated U. S. Earth Probe. France and the U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. QuikScat, which was launched after a one-year development, is providing measurements originally provided by the NASA Scatterometer (NSCAT), which mapped ocean winds for one year prior to an on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation. Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the SeaWifs instrument.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. The first is the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission. The second is the CloudSat mission. Both are scheduled for launch in 2003. The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS Flight Model-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency has completed its re-planning and will be ready to fly FM-5, as QuikToms, on a US vehicle and spacecraft in August 2000.

In developing its measurement/mission strategy, the Earth Science Enterprise desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each successive future mission in the ESE flight program will be based on specific solicitation alternatives (e.g. Announcement of Opportunity, Request for Proposal, etc.) and competitive selection of instrument payloads and implementation options. In each solicitation, we will ask commercial industry to come forward and offer science-quality data that meet NASA requirements. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based space-based measurement concept set is indispensable to guide these pre-mission technology developments, particularly the Enterprise's Instrument Incubator Program. Our goal is to reach a mission development cycle of two-three years from the time of selection.

NASA ESE is developing a science implementation plan, which will drive the selection of Earth observation satellite missions in the 2003-2010 time frame. An early, high priority in this timeframe is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP), which will serve to provide continuity with the Terra and Aqua missions as well as a demonstration of instruments for the converged weather satellite program. NASA and the Integrated Program Office (IPO) jointly fund the NPP mission. The IPO consists of representative from the three agencies participating in NPOESS – NASA, the National Oceanic and Atmospheric Administration, and the Air Force.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government—anyone who wants the information.

Following the recommendation of the National Research Council, NASA is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products. This is part of a broader analysis of how ESE's approach to data and information systems services should evolve in the future.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every state within the U. S. are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with U. S. researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to two scientists who first recognized that cholorflorocarbons provided a threat to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

From FY 2000 on, there is increased emphasis on a viable Applications, Commercial and Education (ACE) program that bridges our focused Research and Analysis (R&A) and mission science investments with the Applications and Commercial Remote Sensing Program towards demonstration of new remote sensing data products for industry and regional and local decision makers. The need is to focus on the dissemination of information to non-traditional Earth science customers, such as States, counties and regional managers and decision-makers. This budget identifies initial funding requirements for the Digital Earth Initiative designed to develop usable, remote sensing-based information products for state and local users around the Nation and beyond. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually we hope that our demonstration of this concept will allow products to reach a much broader user base – practically every state in the Union.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. NASA's Earth science research program constitutes its contribution to the U.S Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten U. S. government agencies. NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the NOAA on climate-related issues. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DoD) jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the USGS on a range of land surface, solid Earth and hydrology research projects. NASA and USGS collaborate in the Landsat-7 program, and NASA, DoD and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations, including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine and others.

In addition to ensuring a robust science program, this budget contains a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes the New Millennium Program (NMP), Instrument Incubator and High Performance Computing and Communications (HPCC), an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia.

Technology efforts will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations;
- Cutting-edge technologies, processes, techniques and engineering capabilities that reduce development, operations costs, and mission risk and that support rapid implementation of productive, economical, and timely missions;
- Advanced end-to-end mission information system technologies: technologies affecting the data flow from origination at the instrument detector through data archiving, for collecting and disseminating information about the Earth system, and enabling the productive use of Enterprise science and technology in the public and private sectors.

Terra (formerly AM) was recently launched on December 18, 1999. Terra will provide key measurements that will significantly contribute to our understanding of the total Earth system. The instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 was also launched in 1999. Landsat-7's single instrument, the Enhanced Thematic Mapper Plus (ETM+), is making high spatial resolution measurements of land surface and surrounding coastal regions. This mission is successfully providing data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, and other civil and commercial purposes.

With the EOS missions, such as QuikScat, Terra, Landsat-7, and ACRIMSAT that were launched in 1999, NASA is beginning to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users such as regional Earth science applications centers, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M (1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, had been planned for launch in 1999. At this time it is uncertain that the Russians will meet their commitment to be ready to launch SAGE III in FY 2000. The instrument is completed and in storage at LaRC in the meantime but will not be shipped due to safety related issues until the spacecraft is ready to accommodate its integration. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M (2) spacecraft had planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. This past year, NASA learned that Russia would not be able to meet its goals for producing a spacecraft and launch vehicle for the TOMS instrument. Since then, NASA and the RSA mutually agreed to terminate cooperative activities on the project and we are currently implementing QuikToms using an U.S. provided launch vehicle and spacecraft.

The QuikScat spacecraft was launched in April 1999. QuikScat, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS 1, which failed in June 1997 after seven months on-orbit, and ADEOS II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but the ESE still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. It now appears that ADEOS-II will be launched no earlier than late 2001 with the delay due in part to a failure of a Japanese launch vehicle.

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) was launched on December 20, 1999 providing for the continuation of the long-term, quantitative understanding of the solar forcing of Earth's climate.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE
EARTH OBSERVING SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Terra	31,800	6,200
Aqua (formerly PM-1)	113,100	92,800
Chemistry	132,800	124,700
Special Spacecraft	116,000	120,400
QuikScat	11,400	1,100
Landsat-7	17,000	9,600
Algorithm Development	116,800	121,700
EOS Follow-on	4,500	24,400
Technology Infusion	89,000	74,515
Total	632,400	575,415

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE
EARTH OBSERVING SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Terra	[31,800]	[6,200]	3,100
Launch Services	[4,200]	--	--
Aqua (formerly PM-1)	[113,100]	[92,800]	42,900
Chemistry	[132,800]	[124,700]	110,300
Special Spacecraft	[116,000]	[120,400]	86,700
QuikScat	[11,400]	[1,100]	--
Landsat-7	[17,000]	[9,600]	1,400
Algorithm Development	[116,800]	[121,700]	82,100
EOS Follow-on	[4,500]	[24,400]	120,600
Total	[547,600]	[500,900]	447,100

Note: in the new proposed structure, Technology Infusion is located under Research and Technology.

PROGRAM GOALS

The overall goal of the Earth Observing System (EOS) is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are to:

(1) Create an integrated, scientific observing system emphasizing climate change that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes.
(2) Develop a comprehensive data information system, including data retrieval and processing system.
(3) Serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make Earth science data and information publicly available.
(4) Acquire and assemble a global database for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

STRATEGY FOR ACHIEVING GOALS

The EOS contributes directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments, which will fly aboard the EOS spacecraft, and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the USGCRP global change science priorities and the assessment by the Intergovernmental Panel on Climate Change of the scientific uncertainty associated with global climate change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM) renamed Terra, afternoon (PM) renamed Aqua, and Chemistry missions. Beginning in 1999, 2000, and 2002 respectively, the satellites will be flown for a period of six years. Additional observations are provided by the Landsat-7 mission, successfully launched on April 15, 1999.

Nearly all-key EOS missions include international contributions. For example, the Terra spacecraft is flying an instrument from Canada Measurements of Pollution of the Troposphere (MOPITT) and one from Japan (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)); Aqua will include the Japanese Advanced Microwave Scanning Radiometer (AMSR) instrument and the Humidity Sounder for Brazil (HSB). Chemistry will include the Dutch-Finnish Ozone Monitoring Instrument (OMI) as well as the High-Resolution Dynamics Limb Sounder (HRDLS) instrument jointly produced by the U.S. and the United Kingdom. In addition, numerous agreements have been signed for joint data exchange and distribution, including cooperation in EOSDIS.

The 1997 Biennial Review completed the shift in planning for future missions (i.e., beyond the EOS first series). Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission

design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive approach to acquiring Earth science data.

The ESE recognizes that the pathways of global change research lead from specialized studies of fundamental processes to the integration of individual findings into interactive models of the global Earth system, which can eventually deliver reliable predictions of natural or human-induced environmental phenomena. Long, consistent time-series of global environmental measurements are needed to document changes in forcing parameters and corresponding variations in the state of the Earth system, as required to explore the range of natural variability and test mathematical models of the phenomena. While diagnostic studies based long time series of global measurements can reveal the nature of the underlying mechanisms, focused process studies are indispensable to identify and model the basic physical, chemical and biological processes involved. Understanding these component processes is crucial in order to achieve the goal of constructing reliable predictive models of the Earth system. For this reason, the ESE aims to achieve a proper balance between long-term systematic measurements of key forcing or response parameters, and specialized process research. NASA ESE is in the process of developing a science implementation plan, which will drive the selection of the follow-on missions.

Terra

A new generation of Earth science began with the launch and checkout on December 18, 1999 of Terra - one that studies the Earth as a global system. Because the Terra spacecraft primarily observes terrestrial features, a morning equatorial crossing time is preferred to minimize cloud cover over land. Terra carries a complement of five synergistic instruments. The Clouds and Earth's Radiant Energy System (CERES) instrument will perform measurements of the Earth's "radiation budget" or the process by which the Earth's climate system maintains a balance between the energy that reaches the Earth from the sun, and the energy that radiates from Earth back into space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds. The Multi-angle Imaging Spectroradiometer (MISR) will measure the variation of the surface, aerosol, and cloud properties with the direction from which the Earth is viewed from space (Most other instruments only measure one such direction at a time, while MISR measures nine directions simultaneously). Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will measure atmosphere, land, and ocean temperature, and moisture profiles, snow cover, and information about the state of the biosphere on both land surface and under the top layers of the ocean. The Canadian MOPITT instrument is an infrared gas-correlation radiometer that will take global measurements of carbon monoxide and methane in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument, provided by Japan, will measure cloud properties, vegetation index, surface mineralogy, soil properties, surface temperature and obtain digital elevation modes. The primary contractors associated with the project are Lockheed Martin Missiles and Space (LMMS) for the Terra spacecraft, Raytheon Sensors and Electronic Systems for the MODIS instrument, TRW for the CERES instrument (the instrument has also been flown on the TRMM in 1997), and Lockheed Martin Commercial Launch Services for the Terra Atlas Centaur/IIAS launch service.

Aqua (formerly PM-1)

The research focus of the Aqua spacecraft is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of

numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the project are TRW for the common spacecraft to be used for Aqua; Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS) instrument; and Aerojet for the Advanced Microwave Sounding Unit-A (AMSU-A) instrument. Japan will provide the AMSR-E instrument for the Aqua spacecraft and Brazil will provide a microwave instrument, the HSB. The launch of Aqua is scheduled for December 2000. Boeing provides the launch vehicles and services for the EOS-Aqua mission.

Chemistry

The Chemistry mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D developments. The Tropospheric Emission Spectrometer (TES), the Microwave Limb Sounder (MLS), and the High-Resolution Dynamics Limb Sounder (HIRDLS) have completed their Preliminary Design Reviews (PDR) in 1997 and 1998 and are now reaching a high level of design maturity. The Ozone Monitoring Instrument (OMI) will provide information on the distribution of ozone, aerosols, and several other trace atmospheric constituents. The Netherlands and Finland contribute it. The OMI has successfully completed its PDR in December 1998. The launch of Chemistry-1 is scheduled for December 2002.

Special Spacecraft

The Special spacecraft will be designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Ball Aerospace and Technologies Corporation was responsible for developing the Stratospheric Gas and Aerosol Experiment (SAGE III) that is planned to fly on a Russian spacecraft in 2000, if the Russian launch vehicle and spacecraft are ready. A second SAGE III instrument is scheduled to fly aboard the International Space Station in 2003, and a third instrument has been built and is awaiting identification of an appropriate flight opportunity. The SAGE III will take advantage of both solar and lunar occultation to measure aerosol and gaseous constituents of the atmosphere. The Japanese will provide the Advanced Earth Observing System II (ADEOS II) spacecraft for the Seawinds instrument to measure ocean surface wind velocity as a follow-on to the NASA Scatterometer instrument on ADEOS-I and the Seawinds instrument on QuikScat. The Radar Altimetry mission, Jason-1, will be a follow-on to the TOPEX/Poseidon as a cooperative joint mission with the French Space Agency (CNES), with data provided to NOAA for operational purposes. The EOS Laser Altimetry mission was renamed Ice, Clouds and Land Elevation Satellite (ICESat) to denote its primary objectives of measuring ice sheet height and volume for long-term climate variability studies. The EOS ACRIMSAT will continue the measurement of Total Solar Irradiance (TSI) begun by the ACRIM instruments on the Solar Maximum Mission and UARS.

The Total Solar Irradiance Mission (TSIM) was merged with the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) Mission to form the Solar Radiation and Climate Experiment (SORCE) Mission. SORCE will accomplish all the original science objectives of both TSIM and SOLSTICE including those requirements defined by the National Polar-orbiting Operational Environment Satellite (NPOESS). The SORCE spacecraft will be launched in July 2002.

The ESE is committed to provide a launch vehicle for the Canadian SciSAT mission. Reductions of funds in FY 2000 will be somewhat alleviated since the planned launch date for the SciSAT has slipped several months from December 2001. The launch vehicle payment schedule will be renegotiated in FY 2001 to fully meet our commitment.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite has been returning excellent images, which meet or exceed NASA's expectations. First data was available to public mid-August 1999. By agreement with the United States Geological Survey (USGS), NASA is operating and funding operations in FY 2000. Beginning in FY 2001, the USGS will operate the Landsat-7 system. The Landsat-7 Government/industry team received the American Institute for Aeronautics and Astronautics award.

EOS Follow-On

The next generation of EOS missions will provide new technology and space systems to meet the scientific needs for the NASA Earth science projects. NASA ESE is in the process of developing a science implementation plan, which will drive the selection of future missions. Preliminary mission studies have suggested possible technology needs as an input to technology project planning. New instrument technologies will be tested, validated, and made available to support science proposals for selection of measurements, principal investigators, and instruments for the next EOS missions. All EOS measurements, principal investigators, and instruments will be selected as a result of a broad agency announcement that will include peer review, with the goal of a first planned follow on launch for FY 2004. Launches are expected each year through 2009.

In September 1998, NASA, NOAA and DOD agreed jointly to investigate the feasibility of a joint venture to provide continuity of key climatic changes of global observations and provide risk reduction demonstration of key National Polar-orbiting Operational Environmental Satellite System (NPOESS) sensors, algorithms and processing prior to the first flight of the NPOESS. In April 1999, NASA, NOAA and DOD agreed to jointly formulate this vision under the management of NASA and the Integrated Program Office (IPO). The NPOESS Preparatory Project (NPP) mission is a continuation of key measurements from Terra and Aqua with the end of their operational life. The tentative launch date is 2005. The mission is in formulation studies anticipating a formal authority to proceed in the spring of 2001.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

Seawinds
Plan: May 1995
Actual: May 1995

Meteor-3M Stratospheric Aerosol & Gas Experiment (SAGE III)
Plan: July 1995
Actual: July 1995

Aqua (formerly PM-1)
Plan: April 1997
Actual: April 1997

Jason
Plan: June 1997
Actual: June 1997

ACRIM
Plan: March 1998
Actual: March 1998

ICESat
Plan: June 1998
Actual: June 1998

Chemistry
Plan: March 1998
Actual: October 1999

Rescheduled following completion of alternative configuration studies.

SORCE
Plan: May 1999
Actual: May 1999

SOLSTICE and TSIM were combined in FY 1999 to make the SORCE mission. The Mission Design Review and the Preliminary Design Review were combined and successfully conducted in May 1999.

NPP
Plan: December 2002

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

ACRIM:
Plan: January 1998
Actual: January 1998

Aqua (formerly PM-1)
Plan: April 1998
Revised: June 1998

Revised schedule due to late start following resolution of protest first reported in the 1998 budget

Jason:
Plan: November 1998
Actual: November 1998

SORCE
Plan: October 2000

Chemistry
Plan: August 2000

Rescheduled following completion of alternative configuration studies.

NPP
Plan: December 2003

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Landsat-7
Plan: December 1996
Actual: September 1998

Terra last instrument
Plan: February 1997
Actual: August 1997

Test anomalies occurred on the MOPITT instrument; which required rework by Canadians.

SAGE-III (Russian)
Plan: December 1997
Actual: September 1998

Due to instrument and detector testing problems.

Seawinds
Plan: March 1998
Revised: March 1999

Delayed due to launch slip by Japan.

Aqua (formerly PM-1) last instrument
Plan: September 1999
Actual: December 1999

Instrument deliveries delayed, first reported in the 1998 budget

ICESat
Plan: October 2000

Chemistry-1 last instrument
Plan: January 2002

Rescheduled following completion of alternative configuration studies.

QuikScat
Plan: May 1998
Actual: May 1998

ACRIM
Plan: October 1998
Actual: June 1999

Instrument delivery changed to fit new launch schedule after selection of launch vehicle and spacecraft vendors.

Jason-1
Plan: March 1999
Actual: September 1999

Revised due to CNES spacecraft need date.

SORCE:
Plan: August 2001

TSIM and SOLSTICE were combined in FY 1999 to create the SORCE mission.

NPP
Plan: October 2004

Algorithm Development (Version 2) - Confirms that the second version of the science software necessary for the production of the standard data products for each mission has been developed and is ready to support launch.

Terra
Plan: February 1998
Actual: February 1998

Aerosol SAGE-III (Russian)
Plan: June 1999
Actual: March 2000

Commensurate with the delay in instrument delivery.

Seawinds
Plan: September 1998
Actual: September 1998

Jason-1
Plan: October 1999
Actual: December 1999

Revised due to delayed selection of science team and revised launch date.

Aqua (formerly PM-1)
Plan: July 2000

Chemistry
Plan: December 2001

ICESat
Plan: January 2001

Revised due to delay selection of science team.

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Terra Plan: July 1999 Actual: December 1999	Due to RL10-11 engine standdown, the Terra launch was delayed until the launch vehicles were returned to a flight readiness status. Terra was successfully launched on December 18, 1999.
QuikScat Plan: April 1999 Actual: June 1999	Delayed due to USAF Titan IV failure investigations and launch site availability conflicts.
Landsat-7 Plan: April 1999 Actual: April 1999	Landsat-7 was successfully launched on April 15, 1999.
ACRIMSAT Plan: November 1999 Revised: December 1999	ACRIMSAT was successfully launched on December 20, 1999.
Aerosol SAGE-III (Russian) Plan: September 1999 Revised: TBD	Instrument ready. Awaiting Russian readiness to accept payload.
Seawinds (ADEOS-II) Plan: November 2000 Revised: November 2001	Instrument delivered and integrated onto the spacecraft. Delay due to Japanese launch vehicle problem.
Jason 1 Plan: May 2000 Revised: TBD	All NASA instruments were delivered to CNES in 1999. Delayed to accommodate satellite and altimeter development by French Space Agency (CNES) partner.
Aqua (formerly PM-1) Plan: December 2000	
Chemistry Plan: December 2002	
ICESat Plan: January 2002 Revised: July 2001	Project schedule accelerated due to acquisition of spacecraft bus through the Rapid Spacecraft development procurement mechanism
SORCE: Plan: July 2002	TSIM and SOLSTICE were combined in FY 1999 to the SORCE mission.
NPP Plan: December 2005	

ACCOMPLISHMENTS AND PROPOSED RESULTS

Terra

In April 1999, the spacecraft was delivered to the Astrotech commercial launch processing facility at the Vandenberg AFB, California, where system end-to-end testing was performed and launch preparations were completed. The Delta Flight Operations Review was successfully completed. Terra was successfully launched on December 18, 1999.

Aqua (formerly PM)

During FY 1999, fabrication of the spacecraft structure was completed with subsystem integration onto the spacecraft initiated. All of the six instruments have been delivered for integration onto the spacecraft. Instrument integration onto the spacecraft will continue through January 2000. The Pre-Environmental Review is scheduled for February 2000 with the test program to follow. Shipment to the Western Test Range is planned for November 2000, which is consistent with the manifested launch readiness date of December 2000. Final science instrument algorithms are on plan and the ground system operations are proceeding in support of the December 2000 launch. Observatory and instrument checkout will occur for approximately 90 days after launch wherein nominal mission operations will commence.

Chemistry

The Chemistry mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D development. The HIRDLS instrument completed CDR in April 1999, the TES completed its CDR in June 1999, and the MLS completed its CDR in September 1999. All of these instruments have reached a high level of design maturity. The Netherlands and Finland contribute the OMI instrument. The OMI CDR was held in October 1999.

The Spacecraft delta PDR was held in November 1999 to assess what changes would need to be incorporated into the common spacecraft bus to accommodate the Chemistry Mission. The successful delta PDR showed that many of the spacecraft subsystems have already reached a CDR level of maturity. The Launch of Chemistry is scheduled for December 2002.

Special Spacecraft

The Jason MOU between NASA and CNES was signed in December 1996. CNES will provide the spacecraft, solid-state altimeter, and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) positioning system. NASA will provide the microwave radiometer, global positioning system and laser retroreflector array. The ground system and mission operations will be shared. NASA will also provide the launch services. Delays in the CNES satellite development program and altimeter development have caused the launch of Jason to be rescheduled. A revised launch date has not yet been determined. NASA supported a Jason-1 PDR in June 1997 and initiated the Boeing Delta II launch vehicle contract in September 1997.

The Jason activities for 1998 focused on the completion of the critical design for all flight elements. Engineering model development and test is complete for the technologically difficult altimeter and microwave radiometer instruments. The CDRs for these instruments were both held early in 1998 to support a system-level CDR for the satellite in June 1998. Flight models of the

instruments were built during the second half of 1998 for delivery to the payload integration activity at CNES next year. Another critical activity under way in 1998 was the design and development of the Dual Payload Attach Fitting (DPAF) an addition to the launch vehicle structure that would accommodate the dual Jason/TIMED payload on the Delta II launch vehicle.

CNES held the system-level CDR for the Jason mission with NASA support in the fall of 1998. Simulators or engineering models of all the instruments were delivered to CNES, who will perform platform and payload integration and test as separate activities. The flight models of all the instruments were delivered by September 1999. Satellite-level integration and test began in late 1999. CNES will ship the integrated satellite for Jason to the Western test range and launch is co-manifested with NASA's TIMED space science satellite. Launch was initially scheduled for May 2000 on the Delta Launch vehicle but will be rescheduled for a later date due to CNES satellite and altimeter development problems. After launch and a 60-day checkout, normal mission operations are scheduled to begin, including formation flying with the TOPEX/Poseidon satellite, to provide cross correlation for scientific trend analysis of the sea-surface height.

The ICESat team successfully completed the Mission Design Review (MDR) in December 1998 and the Geoscience Laser Altimeter System (GLAS) Critical Design Review (CDR) in March 1999. The ICESat launch vehicle was selected in April 1999; ICESat is comanifested with the CATSAT mission on a Delta 7320. The Control Center effort was also initiated in FY 1999. Formal review of the GLAS Algorithm Theoretical Basis Document (ATDB) was held in April 1999. Activities for FY 2000 will focus on integration and test of the GLAS flight unit and integration and test of the Ball provided spacecraft. Critical activities for FY 2001 include integration and test of the GLAS instrument with the spacecraft and launch vehicle integration in preparation for launch.

The SOLSTICE and the TSIM missions were merged into one mission called the SORCE. This occurred in FY 1999 after NASA completed an accommodation study, which examined combining various Earth Science missions. It was determined that there were significant science and financial benefits to be gained from combining both the SOLSTICE and TSIM missions. SORCE is a Principle Investigator (PI) Mode mission lead by the University of Colorado's Laboratory for Atmospheric and Space Physics (LASP). During FY 1999, SORCE conducted a successful MDR in May and a Mission Confirmation Review in June. The ESE confirmed SORCE in August and directed the start of the Implementation Sub-phase. Additionally, LASP selected Orbital Science Corporation to provide the spacecraft bus for SORCE in FY 1999. During FY 2000, key milestones will include the spacecraft bus PDR and CDR. The first flight instrument will be completed (XUV Photometer System). The other instruments on SORCE will complete their engineering models and testing, and flight unit fabrication will begin. The launch vehicle for SORCE will be selected in FY 2000.

Two SAGE III instruments were manufactured for long-term monitoring of ozone and aerosol. One instrument was developed and delivered in 1998 and the second one was delivered in early 1999. The instrument will be shipped to Russia the first quarter of 2000, as long as the Russian launch vehicle is ready. The second mission is scheduled to fly aboard the International Space Station in 2003.

The Seawinds CDR was completed in January 1996. The Seawinds instrument continued to undergo protoflight model fabrication and assembly during FY 1998. The Seawinds instrument activities will consist of integration and test of the instrument. The protoflight model is scheduled for delivery to Tsukuba, Japan in March 1999 for a November 2000 launch on the ADEOS II spacecraft by a NASDA H-II rocket from Tanegashima, Japan. However, the project is expecting a second launch delay by Japan of approximately one year.

The Active Cavity Radiometer Irradiance Monitor (ACRIM) made final preparations for launch in FY 1999 including integration of the ACRIM payload onto the Orbital spacecraft and installation of the ACRIM ground station at table Mountain California. ACRIMSAT was successfully launched from Vandenberg Air Force Base (VAFB) on December 20, 1999. The spacecraft was manifested on a Taurus launch vehicle with the Korean Multipurpose Satellite (KOMPSAT). The Mission and Operations Readiness Review and Risk Assessment Review were completed on November 29, 1999 at VAFB. The spacecraft is being operated from the Orbital Sciences Spacecraft Operations Control Center (SOCC) in Dulles, VA for a 45 day on-orbit post launch checkout period after which operations will be handed off to JPL to perform operations for the remainder of the five-year mission.

QuikScat

The QuikScat mission will fill the ocean-wind vector data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS-I) spacecraft. The NSCAT instrument ceased to function when ADEOS-I failed in 1997. Spares from the follow-on Scatterometer, Seawinds, instrument were used to assemble the QuikScat Scatterometer instrument. Ball Aerospace and Technologies Corporation of Boulder, Colorado was selected in 1997, to provide the QuikScat spacecraft. Ball was selected via the Indefinite Delivery Indefinite Quantity (IDIQ) rapid delivery spacecraft contract. QuikScat was completed in 1998 and launched from Vandenberg Air Force Base on a Titan II in June 1999. QuikScat calibration/validation will be completed in January 2000 and will be delivered to the general science community thereafter.

Landsat-7

The Landsat-7 satellite was launched on April 15, 1999, and declared operational in July 1999. The satellite has been returning excellent images, which meet or exceed NASA's expectations. First data was available to public mid-August 1999. By agreement with the USGS, NASA is operating and funding operations in FY 2000. Beginning in FY 2001, the USGS will operate the Landsat-7 system. The Landsat-7 Government/industry team received the American Institute for Aeronautics and Astronautics award.

EOS Follow-On

NASA ESE is currently developing a science implementation plan, which will drive the selection of EOS follow-on missions. Two of those missions are included in this budget request: NPP and Landsat follow-on.

The NPP preliminary studies were completed in FY 1999 and the project is in formulation leading to an authority to proceed in early 2001. The tentative launch readiness date is late 2005. At present, NASA is responsible for spacecraft development and integration, one instrument, the Advanced Technology Microwave Sounder (ATMS), overall mission integration and science data processing. The IPO is responsible for two instruments, Visible Infrared Imaging Radiometer Suite (VIIRS) and the cross-track infrared sounder (CRIS), ground system development, flight operations and operational data processing.

- The NPP mission: continues filling the EOS 15 year data set for fundamental global climate change observations started by MODIS, AIRS, and a combination of AMSU/MHS/HSB which are the primary instruments on the Terra and Aqua satellites. This is also a precursor mission to the next generation of operational polar weather satellites being developed by the NPOESS Integrated Program Office (IPO), a joint NASA, NOAA, DoD effort. This mission is the result of the ESE extending an invitation to existing and potential satellite operating agencies to join in the development of new remote sensing capabilities that meet both

scientific research and operational applications for operational needs. The cost of this mission will be shared between NASA and the IPO. This arrangement will also help transition these measurements into the future National operational system. ESE will only invest in operational instruments that are co-sponsored by a mission agency, and where there is a clear path for their ultimate integration into the intended operational system(s).

- Landsat follow-on: Continues the basic global land cover change data set. We are hopeful this can be accomplished with a commercial data purchase, and have released a Request for Information as a first step in exploring this avenue.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Earth Observing System Data Information System	261,700	261,906

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 PLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Earth Observing System Data Information System	[261,700]	[261,906]	252,000

PROGRAM GOALS

The goals for the EOS Data Information System (EOSDIS) are the development and operation of a highly integrated system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS, to preserve these and all other Earth science environmental observations for continuing use; and (4) make all these data and information easily available for use by the research, education, government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS facilitates the goals of Earth science by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is based on an evolutionary design to develop capabilities with the phased deployment of the EOS satellites and to enable adaptation to changes in user needs and technology. NASA continues to use of prototypes, as appropriate, to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other projects at NASA and other agencies to fund technology development efforts of a more generic nature, e.g., communications technology. An initial version of the system, Version 0, implemented at eight Distributed Active Archive Centers (DAACs) and through cooperative efforts with NOAA, the USGS, and international partner space agencies, became operational in 1994.

Plans for development of subsequent versions of the EOSDIS have been redrawn. Due to continuing problems and schedule delays with completion of the Science Data Processing Segment (SDPS) and the Flight Operations Segment (FOS), two important components of the EOSDIS Core System (ECS), we have focused ECS work on operational support for the near-term missions (Terra and Aqua) and with post-launch deliveries of software restoring some of the originally planned capability.

The EOSDIS development has been divided into six major components: The EOS Polar Ground Stations (EPGS), the EOS Data and Operations System (EDOS – developed by TRW), the EOSDIS backbone Network (EBNet – developed in-house by GSFC), the ECS – under development by Raytheon), the DAACs and Science Investigator-led Processing Systems (SIPS). The EPGS capture spacecraft science data dumps, and forward them to EDOS for processing. The EPGS also provide a telemetry and command link for controlling spacecraft health and safety. The EDOS receives the raw data stream from the satellites, separates the data by instrument, and performs the initial processing (packet restoration and temporal ordering) and back-up archiving. The EBNet delivers the real-time data to and from the operations control centers and the science data to the DAACs. The ECS includes the FOS, which provides data product generation using science software provided by the PIs, for archival, and distribution. The DAACs currently have an operational capability using EOSDIS Version 0 for the non-EOS data and ECS to support Landsat-7. Using the ECS, the DAACs will process the raw data from EOS instruments into useful products, handle all user product searches, requests, and orders and distribute data and information directly to the user community, primarily via the Internet. The DAACs also archive the data and information for future use. Each DAAC focuses on the data needs of a specific segment of the user community. Instrument teams may propose to produce their standard data products operationally and deliver them to the DAACs in lieu of providing the science software for integration and producing the products at the DAACs using ECS. The instrument teams' systems for such product generation are referred to as SIPS. The decision to use SIPS is made case-by-case depending on cost and technical considerations. The EOSDIS Independent Verification and Validation (IV&V) contract is with the Averstar Corporation.

The EDOS element of EOSDIS has been developed and is supporting the launch and operations of the Terra mission. The EDOS interfaces with the TDRSS ground station at White Sands Complex (WSC) and back up EOS Polar Ground Stations (PGS) in Alaska and Norway. The raw satellite data will be sent from the ground stations to the EDOS Level-0 processing center at Space Flight Center (GSFC), which will process the data and send it to the DAACs. EOS missions following Terra will not use the WSC TDRSS ground stations for science data downlink but will reply on the EPGS.

Using the ECS, or DAAC developed systems, the DAACs will process the raw data from the satellites into useful science products, handle user product searches, requests, orders, and distribute data and information directly to the user community. The DAACs also archive Earth science data and information for future use. To better serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. A user-working group (advisory panel) guides each DAAC.

The eight DAACs are located at:

- Alaska Synthetic Aperture RADAR (SAR) Facility, Geophysical Institute. University of Alaska, Fairbanks, Alaska
- Earth Resources Observation System (EROS) Data Center (EDC), U.S. Geological Survey, Sioux Falls, South Dakota
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center (LaRC), Hampton, Virginia
- National Snow and Ice Data Center (NSIDC), University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Applications Center (SEDAC), Lamont-Dougherty Earth Observatory, Columbia University, Palisades, New York
- Goddard Space Flight Center, Maryland

Currently, EOSDIS Version 0 allows direct access to selected pathfinder data holdings from the USGS and NOAA. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data for EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve data availability to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

NASA is currently looking at future data system needs and designs through a variety of paths. The EOSDIS Working Prototype Federation, in its second year, is developing methodologies for decision making and interoperability in a collaborative, yet competitive, distributed data system topology. The Federation consists of 24 Earth Science Information Partners (ESIPs), the eight DAACs and one EOS science computing facility. Twelve ESIPs focus on research, and science data set production and management while the remainder focus on commercial and extended applications for NASA's Earth Science Data. The Federation members collectively are establishing the rules and requirements for membership in the Federation. NASA has also begun long-term planning for the evolution of the current Earth Science data system. A team of Earth and information scientists along with NASA managers has been working on a high-level concept for a new Data Information Systems and Services (New DISS). New DISS refers to the distributed Earth science data system and services which, over the next 6-10 years, will evolve after the EOSDIS. New DISS will consist of a heterogeneous mix of interdependent components derived from the contributions of numerous individuals and institutions. These widely varying participants will be responsible for data management functions including data acquisition and synthesis, access to data and services, and data stewardship. Because the NASA ESE already has made considerable investment in existing data system activities (e.g., DAACs, the ECS, the ESIPs), and in product generation, the near-term NewDISS will necessarily

leverage off of these existing components. However, the future NewDISS components could be quite different, as data systems and services evolve to meet science-driven demands and to take advantage of technological innovation. The report from the New DISS planning team will be produced in 2000.

SCHEDULE AND OUTPUTS

EOSDIS Version 1 Plan: January 1997 Revised: Replaced	Provide support for science data processing, archival, and management of the data from the two EOS instruments operating on the TRMM spacecraft. The ECS contractor failed initial test readiness for EOSDIS Version 1 and NASA issued a Stop Work Order. Replacement systems were developed at GSFC and LaRC, (extended "Version 0" in-house system), and the systems are performing successfully.
EOSDIS Version 2 Plan and actual: January 1999 through December 1999	Provide support the launch of Terra and Landsat-7. Technical difficulties by the ECS contractor have required a descope in the original requirements planned for Version 2. NASA issued a Change Order to Raytheon for reduced requirements set (A+). The requirements were provided in a set of incremental deliveries beginning in January 1999 and ending in December 1999.
EOSDIS Version 3 Plan: June 2000 Revised: December 2000	Provide science processing and flight operations support for Aqua and ICESat. Will support flight operations and science processing.
EOSDIS Version 4 Plan: December 2000 Revised: April 2001	Provide science processing and flight operations support for Chemistry. Will support flight operations and science processing. Provides final increment of ECS A+ requirements.

Providing broad and efficient access to data products is key to meeting the Agency mission of advancing and communicating scientific knowledge. The successful functioning of EOSDIS is essential to the accomplishment of all three of Earth science's strategic goals. EOSDIS has been routinely providing and will continue to provide Earth science data products to end-users within five days of receipt or production of the requested data product. These products comprise data from currently operating space assets including: precipitation measurements and observations of tropical storm from the Tropical Rainfall Measurement Mission (TRMM), ocean productivity measurements from the Sea-viewing Wide Field-of-view Sensor (SeaWifs), detection of ocean surface height changes used to predict El Nino occurrence and strength from the Topex/Poseidon Mission, and sea ice motion and Antarctic mapping from Canada's RADARSAT. The data provided also include: measurements of stratospheric trace chemicals from the Upper Atmospheric Research Satellite (UARS), Antarctic Ozone Hole measurements from the Total Ozone Mapping System (TOMS), land use and land cover data from the heritage Landsat missions, and measurements of the earth and solar radiation from the Earth Radiation Budget Experiment (ERBE).

Some key indicators of DAAC performance are the volume of data archived (approximately 284 terabytes at the end of FY 1999), the number of users accessing the DAACs (just under 1.3 million distinct users accessed the DAACs in FY 1999), and the number of data products delivered in response to user requests (approximately 5.2 million data products delivered in FY 1998). Metrics will also be tracked that capture the degree of user satisfaction, which will provide ESE with information that shows how well we are meeting customer expectations in providing data.

ACCOMPLISHMENTS AND PROPOSED RESULTS

The ECS FOS supported a December 1999 launch of the Terra spacecraft after the successful replacement of deficient real time command and control software with a Raytheon developed spacecraft control system called "Eclipse". The Eclipse software has been integrated with the other components of the FOS system as well as other elements of the EOS ground system, and has been extensively tested and exercised during a number of tests with the Terra spacecraft and instruments during FY 1999. The FOS Instrument Support Toolkits (ISTs), which allow instrument operations teams to plan for the operation of their instruments and monitor instrument performance from their home institutions, were installed at the primary operations sites for the Terra instrument teams.

Development of the ECS SDPS has stabilized this year. The baseline system for support of Landsat-7 and Terra was deployed to the GSFC, LaRC, EDC and NSIDC DAACs. Extensive ground system testing was conducted in preparation for the Landsat-7 launch. Landsat-7 data ingest, archival and distribution operations were initiated at the EDC DAAC, utilizing the ECS, shortly after launch in April 1999. The DAAC began distributing data to the general public in September 1999. Extensive testing and operations readiness activities have also been underway in preparation for the Terra launch. A series of progressively longer and more operationally complex system end-to-end tests were conducted, beginning in January 1999 with 24 hour tests to verify system performance requirements, and concluding in October 1999 with a successful 5 day Terra mission operations simulation involving all science system components. During 1999, requirements for higher level MODIS instrument data processing (Level 2 and 3 products) were transferred to the MODIS science computing facility, which became the first operational "SIPS". The higher level products will still be archived and distributed by the GSFC, EDC and NSIDC DAACs. The CERES Instrument Team has also opted to process, archive and distribute their data from the same LaRC DAAC system developed to support CERES on TRMM.

The ECS Science and Flight Operations Systems were both verified to be compliant with Y2K this year.

The EOSDIS will continue to work to meet its planned performance target of successfully disseminating Earth science data to enable our science research and applications goals and objectives. Indicators of this activity will be making available acquired observations and information on land surface, and climate to users within 5 days of acquisition and improving on prior year targets for archive, distribution and number of customers served.

The ECS contract has been restructured, scaling back on some lower priority requirements, and adding new requirements for support of future missions such as Aqua, ICESat, and Chemistry. The Raytheon proposal was evaluated, and negotiations were conducted during this year. A sound cost and schedule baseline has been established, on which the contractor's future performance will be measured.

Other elements of EOSDIS needed to support the Terra mission continued on schedule. The EDOS and the EBNET were delivered and are ready to support command uplink and data acquisition for the Terra Mission. The GSFC and LaRC DAACs have successfully supported science processing and data management for the CERES and LIS instruments on TRMM since the TRMM launch in November 1997.

The EOSDIS Federation experiment continued for its full year in 1999. The 24 Working Prototype Earth Science Information Partners (WP-ESIPs) have been developing science products, collaborating with one another as a single entity and in "clusters" and collective management and data set interoperability. The 24 WP-ESIPs, along with the DAACs, and the science computing facility members of the Federation experiment, represent the broad science and applications community and include representatives from educational, industry, regional governments and consortium, and NASA data centers. Implementation of the federation is being carried out in parallel with the development of EOSDIS and the DAACs

NASA began long-term planning for the evolution of the current Earth Science data system in FY 1999. A team of Earth and information scientists along with NASA managers began work on a high-level concept for a new NewDISS which will evolve from the current EOSDIS, working prototype Federation research, and other ESE mission data systems.

A key focus in 1999 was the review of the eight DAACs by the National Research Council (NRC). The NRC reviewers visited each DAAC and assessed its effectiveness through interviews with DAAC customers. NRC is currently finalizing their report on the DAAC peer review. The NRC released a preliminary report in early FY 1999 and NASA and the DAACs have been reviewing the report and responding to NRC recommendations. Overall, the review was laudatory of the DAACs and the EOSDIS system and provided some very insightful recommendations for improving the DAACs support for Earth science.

In 2000, the ECS Science System will be upgraded to improve user interface services, add capabilities required for support of Aqua instruments, increase system capacity, and upgrade to newer versions of COTS products. A Performance Verification Center (PVC) will be established to provide an environment for testing performance of new releases, prior to deployment to operational DAACs. Major releases are planned in April and December 2000.

The Federation Experiment and the WP-ESIPs will continue their important collaboration in 2000, the final year for the experiment. The Federation will develop a constitution and by-laws outlining the rules and requirements for membership in the Federation. The WP-ESIPs will be busy completing their science data set productions and achieving smooth operations as a federation. NASA will complete their evaluation of the experiment and decide on the feasibility and strategy for evolving EOSDIS into a federated architecture.

A key milestone for 2000 will be NASA ESE response to the NRC report on the peer review of the ESE DAACs. A NASA management team will finalize their evaluation of the report and make recommendations to the NRC and to the Associate Administrator for Earth science.

ESE will continue tracking the three key indicators of DAAC performance. In FY 2001 the volume of data archived will increase by 20% compared to FY 2000 (targeting approximately 442 terabytes). The number of users accessing the DAACs will increase by 20% compared to FY 2000 (targeting approximately 1.5 million). The number of data products delivered in response to user requests will increase by 10% compared to FY 2000 (targeting approximately 5.4 million data products delivered).

In FY 2001, operations and completion of the EOSDIS will be the primary tasks. Additional EOSDIS Core System (ECS) software deliveries in FY 2001 to support the requirements for the Aqua, Chemistry, and ICESat missions. Higher level processing of the science data products from Aqua and Chemistry will be accomplished at the DAACs or by the instrument science teams at their institutions as appropriate, while the EOSDIS DAACs will provide data archival, distribution, and user support. Additional EOSDIS functionality will be delivered to further automatic operations and user services. A key focus will be on implementing a new, web-based user search and order interface.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH PROBES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	9,900	24,800
Earth System Science Pathfinders	62,300	94,500
VCL	19,700	21,300
GRACE	30,300	24,800
PICASSO-CENA	5,000	25,200
CloudSat	2,000	19,300
Volcam alternate mission	100	400
Program Support/Future missions	5,200	3,500
Experiments of Opportunity	2,100	1,000
Triana	35,000	35,100
University Class Earth System Science	--	2,000
Total	109,300	157,400

BASIS OF FY 2001 FUNDING REQUIREMENT

MAJOR DEVELOPMENT

PROPOSED NEW STRUCTURE

EARTH PROBES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	[9,900]	[24,800]	500
Earth System Science Pathfinders	[62,300]	[94,500]	105,900
VCL	[19,700]	[21,300]	2,600
GRACE	[30,300]	[24,800]	8,900
PICASSO-CENA	[5,000]	[25,200]	35,400
CloudSat	[2,000]	[19,300]	49,800
Volcam alternate mission	[100]	[400]	--
Program Support/Future missions	[5,200]	[3,500]	9,200
Experiments of Opportunity	[2,100]	[1,000]	500
Triana	[35,000]	[35,100]	2,000
University Class Earth System Science	--	[2,000]	11,500
Shuttle Radar Topography Mission	--	[6,200]	--
Total	[109,300]	[163,600]	120,400

Note: SRTM has been added to the proposed new structure.

PROGRAM GOALS

The Earth Probes program is the component of Earth science that addresses unique, specific, highly focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts, small satellites and advanced technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements on short development cycle of 1-3 years. The currently approved Earth Probes missions are the Total Ozone Mapping Spectrometer (TOMS), Triana, and Earth System Science Pathfinders (ESSP) missions. NASA has added the University Class Earth System Science (UnESS) pathfinders to the Earth Probes program.

STRATEGY FOR ACHIEVING GOALS

TOMS

The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on a Russian Meteor-3, launched in 1991, a TOMS (flight model 3) launched on the Japanese ADEOS in 1996 and the Earth Probe spacecraft also launched in 1996. The remaining development TOMS project consists of one instrument (flight model 5, designated FM-5). The FM-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency has completed its re-planning and will fly FM-5, as QuikToms, on a US vehicle and spacecraft in August 2000.

ESSP

The ESSP is a science-driven project intended to identify and develop in a short time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current projects. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the Earth science program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The first two ESSP missions and an alternate mission were selected in March 1997. The Vegetation Canopy Lidar (VCL) mission led by a University of Maryland, College Park Principal Investigator, with spacecraft and instrument delivery expected in early 2000 and a scheduled launch date of September 2000. The second mission, Gravity Recovery and Climate Experiment (GRACE) which is led by a Principal Investigator from the University of Texas at Austin with significant participation by the German Aerospace Center (DLR), completed formulation and has begun its implementation with launch expected in June 2001. A minimum amount of funding was provided to the Chemistry and Circulation Occultation Spectroscopy Mission (CCOSM) to maintain this mission as an alternate to replace VCL or GRACE if significant difficulties developed. Given that the first two ESSP missions are in the implementation sub-process, CCOSM has been discontinued as an alternate mission. A final CCOSM report has been provided to NASA.

The second ESSP Announcement of Opportunity (AO) was released in the third quarter of FY 1998. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission was selected in December 1998 is led by NASA's LaRC and is scheduled for launch in 2003. PICASSO-CENA is designed to address the role of clouds and aerosols in the Earth's radiation budget. It will employ innovative Light-Detection and Ranging (LIDAR) instrumentation to profile the vertical distribution of clouds and aerosols, while another instrument will simultaneously image the infrared emission of the atmosphere. During the daylight half of its orbit, PICASSO-CENA will measure the reflected sunlight in an oxygen absorption band and take images of the atmosphere with a wide-field camera. The total estimated mission cost of PICASSO-CENA, including launch vehicle, is $168.3 million, of which NASA will provide $112.2 million. The remaining funding is contributed through the French Space Agency for the spacecraft bus. PICASSO-CENA will be launched in 2003. It consists of a partnership between the LaRC, France's Centre Nationale D'Etudes Spatiale (CNES), the Institute Pierre Simon LaPlace, Hampton University of Hampton, Virginia (a Historically Black University), the Ball Aerospace and Technology Corporation and the GSFC and the KSC. France is providing a PROTEUS spacecraft, the infrared imaging system, and science analysis support.

In addition, NASA chose two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study in December 1998. Based on the study results completed in March 1999, NASA has selected CloudSat for full development as an ESSP AO#2 mission. VOLCAM was selected as the alternate mission. CloudSat is a two-year data set pathfinder mission designed to advance the understanding of the cloud-climate feedback problem. The mission is focused on understanding the role of optically thick clouds on the Earth's radiation budget using advanced cloud-profiling radar. CloudSat has been dual manifested with the PICASSO-CENA mission on a Delta launch vehicle scheduled for launch in 2003. CloudSat is collaboration between the United States, Canada, Germany, and Japan, and is managed by the JPL. It consists of a partnership between JPL, Colorado State University, the Canadian Space Agency (CSA), Ball Aerospace, the U.S. Department of Energy, the U.S. Air Force, the GSFC and the KSC. The total estimated mission cost of CloudSat, including launch vehicle, is $140.8 million, of which NASA will provide $115.8 million. The remaining funding is contributed through the Department of Energy for calibration efforts, the US Air Force for ground operations, and Canada for instrument components. NASA intends to solicit another set of ESSP missions in calendar year 2000.

Experiments Of Opportunity

This project offers a capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The ESE has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short-term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

Triana

The Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous high definition color view of the full sun-lit disc of the Earth.

During 1998 the mission was studied at GSFC and an AO was released by NASA Headquarters in July soliciting proposals for full Triana mission implementation. A selection was made in November for the Scripps Institution of Oceanography to build and

conduct the Triana mission. Triana will carry the Earth Polychromatic Imaging Camera built by Lockheed Martin Advanced Technology Company, a radiometer built by the National Institute of Standards and Technology, and a plasma magnetometer that measures solar wind built by GSFC and the Massachusetts Institute of Technology. The Triana mission has suspended work per Congressional direction, while the National Academy of Science (NAS) conducts its review of the scientific aspects of the mission.

UnESS

UnESS consists of Spaceborne investigations of modest science scope. These investigations will be lead by U.S. University principal investigators with significant student involvement. The Announcement of Opportunity was released in August 1999, and is expected to lead to an award of up to six Phase A studies. These studies are expected to result in the selection of a maximum of two missions for implementation and expected launch in 2003.

SRTM

The Shuttle Radar Topography Mission (SRTM) is a reimbursable mission with the National Imaging and Mapping Agency (NIMA). In FY 2000, NASA has requested funding for costs associated with cost growth. The SRTM is planned for launch in January 2000.

SCHEDULE AND OUTPUTS

Launch Readiness dates – verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

TOMS FM-5 (QuikToms)
Plan: August 2000

Vegetation Canopy Lidar
Plan: May 2000
Revised: September 2000

The VCL, the first ESSP mission, is scheduled to launch in September 2000. The later launch date relative to the plan reflects the delay in initially selecting and contracting the first ESSP missions, the change in VCL launch vehicle from a Pegasus to an Athena, and delays in instrument and spacecraft bus development.

Triana
Plan: December 2000
Revised: First quarter 2001

Congressional mandated launch delay. The Triana mission has suspended work while the NAS conducts its review of the scientific aspects of the mission.

Gravity Recovery and Climate Experiment
Plan: June 2001

PICASSO-CENA
Plan: Second Quarter, 2003

CloudSat
Plan: Second Quarter, 2003

ACCOMPLISHMENTS AND PROPOSED RESULTS

TOMS

The TOMS FM-5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has delayed this mission until the year 2002 or later due to funding problems. Presently, the Agency has completed its re-planning and will fly FM-5 on a US vehicle and spacecraft in August 2000. This will meet the need of a gap-filler mission to continue acquisition of the Total Ozone data set. This mission is called QuikToms and is currently in the implementation sub-process and completed the mission design review (MDR) in September 1999.

ESSP

The first ESSP AO was released in FY 1996 and the selection occurred in March 1997. The first two missions, VCL and GRACE, are currently in the implementation sub-process phase with scheduled launches in September 2000 and June 2001 respectively. The second ESSP AO was released in FY 1998 and the selections occurred in December 1998 and March 1999. The second two missions PICASSO-CENA and CloudSat are currently in the formulation sub-process phase leading to mission confirmation in 2000. CloudSat has been dual manifested with the PICASSO-CENA mission on a Delta launch vehicle scheduled for launch in 2003. VOLCAM is in the pre-formulation sub-process as an alternate ESSP mission.

Experiments of Opportunity

The Experiments of Opportunity Program is the funding source for NASA's participation in the *Satellite de Applicaciones Cientificas-C* (SAC-C) mission. SAC-C is a joint mission between NASA and the Argentine Space Agency (CONAE). The mission is co-manifested with NASA's New Millennium Earth Orbiter-1 mission and is scheduled for an early 2000 launch. NASA is providing launch vehicle, scalar helium magnetometer and GPS receivers. The Argentines have various instruments such as multispectral scanner, and high-resolution camera, etc. Spacecraft thermal and structural models were tested and qualified in 1998. The magnetic mapping payload has been calibrated as well. SAC-C has completed fabrication, integration and test of the spacecraft and payloads. The mission will be in operation in the year 2000.

UnESS

The UnESS AO was released in August 1999, and is expected to lead to an award of up to six phase-A studies by March 2000. These studies are expected to result in the selection of at least two missions for implementation and expected launch in 2003.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

APPLIED RESEARCH AND DATA ANALYSIS

	FY 1999 OPLAN 12/23/99	FY 2000 PLAN REVISED
	(Thousands of Dollars)	
Earth Science Program Science	323,600	359,404
Operations, Data Retrieval and Storage	76,100	77,100
Total	399,700	436,504

BASIS OF FY 2001 FUNDING REQUIREMENT

PROPOSED NEW STRUCTURE

RESEARCH AND TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Earth Science Program Science	[251,800]	[286,300]	353,200
Applications, Commercialization and Education	[82,900]	[85,704]	69,200
Technology	[103,500]	[96,415]	110,900
Construction of Facilities	[1,500]	[1,000]	--
Total	[439,700]	[469,419]	533,300

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. GLOBE after FY00 has been included under the ACE program. Detail of this content is provided in each of the element subsections below. The Mission Operations section of Operations, Data Retrieval and Storage is now shown separately under Mission Operations.

PROGRAM GOALS

The goal of Research and Technology is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

STRATEGY FOR ACHIEVING GOALS

The Research and Technology program is divided into three components:

- Research that supports basic Earth science research, analysis, and data analysis of related EOS and other mission science data. Included is the suborbital science program of crewed aircraft and uninhabited aircraft available to researchers and PIs. The EOS interdisciplinary science consists of focused research centered on a specific Earth science data set and geared toward a broader probe into Earth science systemic functions. Also included are funding for high performance computing and communications, and the provision of computing infrastructure.

- Applications, Commercialization, and Education that supports applications research (e.g., natural hazards, agriculture, disaster management, etc.) and the transfer of knowledge through outreach and education. The Commercial Remote Sensing Program that funds cooperative efforts with industrial partners aimed at enabling development of a viable commercial remote sensing industry.

- Earth Science advanced technology that supports development of key technologies to enable our future science missions by reducing their development time and cost.

Each of the major components of Research and Technology has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

BASIS OF FY 2001 FUNDING REQUIREMENT

OLD STRUCTURE

EARTH SCIENCE PROGRAM SCIENCE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Airborne Science and Applications	18,100	22,100
Uncrewed Aerial Vehicles (UAV)	1,900	4,000
Commercial Remote Sensing	38,100	30,400
Mission Science Teams	48,100	55,800
EOS Science	46,400	60,300
R&A	161,600	174,600
Education	9,400	12,200
Total	323,600	359,400

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

EARTH SCIENCE PROGRAM SCIENCE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Research and Analysis – Science	[136,000]	[141,800]	163,600
EOS Science	[41,600]	[55,000]	52,200
Mission Science Teams - Research	[48,100]	[55,800]	100,000
Airborne Science and Applications	[18,100]	[22,100]	22,700
Uncrewed Aerial Vehicles (UAV)	[1,900]	[4,000]	5,000
Information Systems	[6,100]	[7,600]	9,700
Total	[251,800]	[286,300]	353,200

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. These changes are reflected in realignment of the following areas to the ACE program: applications portion of R&A, the fellowships portion of EOS Science, and the Commercial Remote Sensing Program. A description of these activities is located in the ACE narrative section.

PROGRAM GOALS

The goal for the Earth Science Research program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of humankind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes that pose risks to society. The science program provides the analysis and integration of critical data and models needed for national and international assessments.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science project is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academies of Sciences. NASA manages the R&A budget according to five areas: Ecosystems and the Global Carbon Cycle, Global Water and Energy Cycle, Climate Variability and Prediction, Atmospheric Chemistry, and Solid Earth and Natural Hazards. The Natural Hazards portion of this latter area is addressed under the Applications, Commercialization and Education program. Overall science questions are being developed in the Science Implementation Plan.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative influence of human activities on its global natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use development. Another priority is to improve understanding and prediction of transient climate variation, such as El Niño anomalies and to characterize and understand the effects of such variations on the terrestrial and oceanic biosphere. Reducing uncertainties in climate predictions a season or a year in advance would dramatically improve agriculture and energy utilization planning. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention is being given to measuring and modeling the effects of climate forcing factors like clouds, solar radiation, aerosols and greenhouse gases in order to improve our assessments of climate trends on time scales of decades to centuries. There is also appreciable effort going into identifying those processes that couple the biosphere and climate. A continuing priority is to understand the causes and consequences of changes in atmospheric ozone and the feedback processes between atmospheric chemical and climate change. Emphasis is also placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented increase of pollutant emissions in rapidly developing regions throughout the world.

EOS science consists of research aimed to assure that the EOS data can be accurately validated to ground, airborne, and other space-based measurements and interdisciplinary investigations geared for a broader probe into Earth science system functions. The former is needed to assure the quality of data produced by EOS instruments, many of which will be producing the first space-based data of their type, while the latter are needed to assure creative use of multiple data types together with research models to address questions associated with the linkage between Earth system components.

The objectives of the mission science team/guest investigators are to analyze data sets from operational spacecraft that support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology.

The airborne science project funds operations of two ER-2s, one DC-8 aircraft, and one P-3B. The project funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to space flight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns in all ESE science areas throughout the world. The ER-2 aircraft, in particular, are unique in that they fly well into the stratosphere and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms. One of these provided support and observations, including over flights of hurricane *Georges*, for an interagency experiment designed to improve our capability to predict hurricane landfall and intensity. The DC-8 aircraft provides a unique "flying laboratory" facility for a broad range of disciplines in atmospheric sciences. The P-3B is used mainly for lower altitude operations. Many process-oriented studies involve the use of two or more aircraft together with ground and or balloon-based instruments.

NASA is implementing an Uninhabited Aerial Vehicle (UAV) science demonstration program in order to provide an opportunity for the Earth science research and applications communities to utilize UAVs in a small number of missions over the next few years. This demonstration program should help to provide experience in the scientific use of UAVs under a variety of operating environments and conditions such as flights of 24 hours and longer duration, higher altitudes at subsonic speeds, and flights in environments hazardous to the onboard pilot in traditional aircraft. Examples of missions enabled by UAVs are those to observe diurnal changes of key atmosphere, oceanic and land surface processes, or missions to observe key Antarctic or volcanic phenomena which have been inaccessible for pilot safety reasons.

The Earth science information system project has been structured to provide a balanced system of high performance computers, mass storage systems, workstations, and appropriate network connectivity between researchers and components of the system. A major portion of the project funding supports operation of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services is provided to a community of approximately 1,400 users representing all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise 25% of the total. The project monitors and participates in advanced technology projects, such as the HPCC program and National Science Foundation's gigabit test bed programs. Project elements at GSFC and JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the project with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

Research (Natural hazards included in FY99 and FY00)	FY 1999 Estimate/Actual	FY 2000 Estimate	FY 2001 Estimate
Number of principal investigators	1,100/1,123	1,100	1,160
Number of research tasks under way	1,525/1,662	1,525	1,580
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	21/7*	12	12
Number proposals received	975/1,327	1,125	1,300
Number of proposals rated very good to excellent	525/pending	550	530
Number of proposals selected	355/pending	360	360
Time to process proposal (selection through obligation)	45 days	30 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	87%/91%	100%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* Estimate revised due to consolidation of solicitations.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Research & Analysis -- EOS Science

In FY 1999, continuing into FY 2000 and FY 2001, the following are significant accomplishments in the areas of Ecosystems and the Global Carbon Cycle, Global Water and Energy Cycle, Climate Variability and Prediction, Atmospheric Chemistry, and EOS Science.

Ecosystems and the Global Carbon Cycle: determining how land cover and climate changes affect agricultural productivity and ecosystem health

The carbon cycle is one of the major Earth system processes influencing global climate. NASA research on the biology and biogeochemistry of ecosystems and the global carbon cycle aims to understand and predict how terrestrial and marine ecosystems are changing. This research theme addresses ecosystems as they are affected by human activity, as they change due to their own intrinsic biological dynamics, and as they respond to climatic variations and, in turn, affect climate. Emphasis is on understanding

the processes of the Earth system that affect its capacity for biological productivity and the role of the biosphere in Earth system function. Understanding the distribution and cycling of carbon among the active land, ocean, and atmospheric reservoirs constitutes a major scientific focus for research.

Accomplishments

Research in FY 1999 advanced models of carbon uptake by terrestrial and marine ecosystems, created quantitative satellite data products, and yielded new understanding of ecosystem processes important for carbon cycling. A second generation of coupled physical-biological ocean models was produced through the Joint Global Ocean Flux Study Synthesis and Modeling Program. Inter-comparisons of a suite of models of terrestrial productivity bounded the upper and lower limits of ecosystem response to changes in global climate, atmospheric carbon dioxide concentration, and land cover change. The Sensor Inter comparison and Merger for Biological and Interdisciplinary Ocean Studies (SIMBIOS) project has developed algorithms to interrelate and compare data sets from different ocean color scanners (emphasizing the Sea Wide-Field-of-View Sensor [SeaWifs]); these algorithms are being used to merge data sets and produce more comprehensive information about global ocean productivity. Satellite-derived evidence of a global ocean productivity response to conditions and of the positive effects of iron fertilization on ocean productivity were published in the open literature, and the measurement of the distribution of different types of phytoplankton was demonstrated. New data products quantifying global tree cover percentage were created using space-based observations as first step toward improving estimates of aboveground carbon storage in global forests. These data products will be used to help quantify carbon storage in the ocean. Resource managers and the fishing industry will also be able to use them to track productivity patterns in the coastal ocean and make decisions about resource management and where to deploy fishing vessels. The studies of iron fertilization will yield an assessment of the potential of for certain regions of the ocean to sequester more carbon than they currently do.

Analysis of carbon uptake and emission data for the Boreal Ecosystem-Atmosphere Study (BOREAS) in Canada and the Northern U.S., and other field studies that employed several differing methodologies (e.g., eddy covariance flux towers, aircraft-based flux measurements, traditional inventory methods, and inverse atmospheric modeling) highlighted important discrepancies among the measurement approaches. This has set the stage for simple tests to reconcile or resolve the differences and, as a direct result, reduce major uncertainties in estimation of regional carbon dioxide fluxes. The results of this research will help to quantify the size of the Northern Hemisphere carbon sink and significantly reduce the error range surrounding it.

The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) drew attention to the effects of low levels of selective logging and understory biomass burning (burning that disturbs the forest, but does not significantly modify the forest canopy) on the occurrence of significant carbon losses from tropical forest ecosystems. This carbon loss is unaccounted for in current carbon budget analyses for the region and has traditionally been difficult to detect using conventional satellite data analysis approaches. This information will help to quantify the South American carbon source due to forest clearing and disturbance and significantly reduce the error range surrounding it. It will also be used to improve estimates of the total area of tropical forest impacted by land use change.

For the terrestrial biosphere, a new data product showing the distribution of global tree coverage was prepared, making use of data from the Advanced Very High Resolution Radiometer (AVHRR) series of instruments. These observations serve as a first step toward improving estimates of aboveground carbon storage in global forests. Such estimates should be dramatically improved when Vegetation Canopy Lidar (VCL) data become available late 2000. These results will be used to quantify aboveground biomass in

rapidly changing parts of the world and, therefore, reduce uncertainties in the amount of carbon sequestered in certain forests recovering from disturbance.

The Landsat 7 satellite was launched successfully on April 15, 1999, and Mission Operations is acquiring 90,000 scenes per year. High quality data distribution began on August 23, 1999, and public announcement was made on August 30, 1999. Seasonal image collection to refresh the global archive began in July 1999, and over 50,000 acquisitions were archived. There has been one global acquisition and a partial refresh in FY 1999. A rate of 2-3 global terrestrial acquisitions a year will be achieved after a full year of operation. Research is underway to quantify the spatial extent of land cover change in global hot spots of land conversion and improve calculations of carbon emissions. This information can be used to create accurate maps of global land cover and quantify rates of change. Land resource managers will used these data products to monitor and manage their lands. Scientists assessing carbon storage in terrestrial ecosystems will use these data to stratify the land surface into categories of carbon uptake or release.

OrbImage is providing SeaWifs data distribution to the science community through a commercial data buy. SeaWifs project has been producing routinely, near-daily global maps since Sept. 1997. In addition to its primary product of ocean color, SeaWifs has also been producing data on the terrestrial biosphere, sediments transport and water-covered regions, and atmosphere aerosols. The launch of Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra will add new information about primary productivity and will greatly improve spatial coverage over that available from SeaWifs. The SIMBIOS project will merge ocean color data from various sensors and thus a consistent time series of ocean color will be established. This information can be used to estimate global ocean productivity and to assess fisheries production and pollution impacts in coastal regions. Analysis of time series of these productivity data will yield improved estimates of coastal carbon uptake and sequestration for various regions of the ocean and may help to locate and quantify the southern ocean carbon sink(s).

Plans

In FY 2000 the SIMBIOS project will merge MODIS ocean color data into the global ocean color time series that began with Ocean Color Temperature Sensor (OCTS) and SeaWifs. Multi-year time series of ocean color data will be used to understand and predict the response of marine ecosystems to climate change. ESE will continue the ocean color time series with 60% global coverage every four days. This will allow continued monitoring of global ocean productivity and identification and quantification of the ocean carbon sink(s).

NASA contributions to the First National Assessment of the Potential Consequences of Climate Variability and Change will be completed. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will participate in the Southern African Regional Science Initiative-2000 (SAFARI-2000) international assessment in Southern Africa. This assessment will quantify the effects of climate variability and management practices on the environment, as well as provides significant information on the transfer of carbon between the atmosphere and the vegetated land surface. This information can be used by land managers to manage the resources on their lands. The information provided for the National Assessment will be used to improve predictive models of land cover change and its impacts on natural resources and environmental quality within the U.S. Scientists and policy-makers will use the data from the SAFARI 2000 campaign to quantify the annual carbon emissions from southern Africa.

We will continue the development of global land cover/use change data set based on Landsat and EOS instruments, at seasonal refresh rate. We will also begin to collect near-daily global measurements of the terrestrial biosphere from instruments on Terra. The Terra data, including derived products that represent the extent of biological activity, will help in the estimation of the role of the terrestrial biosphere in carbon exchange with the atmosphere. This information will be used to develop global and regional carbon budgets for important land cover types.

ESE will provide the first global, regional and country-by-country forest cover inventory in support of national and international needs research and sponsor two regional national assessment studies of environmental variation and natural resources vulnerability. This information can be used by land managers to manage the resources on their lands and by decision-makers in setting policies for natural resource use and/or conservation.

In FY 2001 we will continue to explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets. Indicators of this activity will be to develop a multiyear global time series of phytoplankton biomass and primary productivity for assessing interannual variability in marine ecosystems on regional scales and daily to interannual time scales. ESE will collect near-daily global measurements of ocean chlorophyll and primary productivity using Terra and Aqua satellites, merged with SeaWifs data. Using data from Terra and Aqua we will estimate the efficiency of the carbon uptake by phytoplankton and demonstrate the value of such measurements in assessing carbon and nitrogen cycling in the open ocean. These new advances will lead us to estimating global carbon stocks and the role of land ecosystem and evaluate human impacts on land cover changes. Through use of data from the first Earth System Science Pathfinder (ESSP) mission, the VCL, ESE will be able to develop the first global sample of vegetation height and vertical structure. This information will be used to make accurate estimates of biomass in the ocean and aboveground biomass on the land that will then be used to help quantify carbon storage in their ecosystems.

ESE will continue to explain the dynamics of the global carbon cycle by building improved models and prediction capabilities. The ESE will improve, by at least 15%, the ecological models needed to predict ecosystem responses to global environmental changes through incorporation of field experiment and satellite data. Information will be provided to understand remotely sensed observations to improve efficiency of food and fiber production as well as to verify the performance of a variety of Earth system models. This will be accomplished by extending the long-term 1-4 km satellite record of global terrestrial productivity and its seasonal and interannual dynamics that was begun with the AVHRR. This activity will continue with the near-daily global measurements from instruments on the EOS Terra spacecraft, using primarily the MODIS instrument. These models will be used to predict future carbon dioxide uptake by and emission from the land and oceans as well as increases and decreases in food, fiber, and fisheries production.

Global Water and Energy Cycle: determining how water cycles among land, oceans, and atmosphere as well as impacts on fresh water availability

Ascertaining the rate of cycling of water in the Earth system, and detecting possible changes, is a first-order problem with regard to the issue of renewal of water resources. Current ESE program activities in this area are; establishing the existence (or absence) of a trend in the rate of the global water cycle, investigating the relationships between large-scale climate anomalies and weather patterns, and accurately representing the integrated effect of water vapor absorption and clouds in a way that is suitable for use in

models of climate. The overarching goal is to improve the understanding of the global water cycle to the point at which useful predictions of regional hydrologic regimes can be made. This predictive capability is essential for practical applications to water resource management and for validating scientific advances through the test of real-life prediction.

Accomplishments

In FY 1999 the Earth Science Enterprise continued to invest in observations, research, data analysis, and modeling in this area. The Tropical Rainfall Measuring Mission (TRMM), launched in 1997, completed its second year of gathering information on rainfall in the tropics where two-thirds of global precipitation falls, and about which there had been little knowledge of its distribution. This is the key to understanding Earth's hydrological cycle, one of the three major processes driving Earth's climate and the global heat balance which drives seasonal change. The data from these measurements is available through EOSDIS. Based on these measurements, the uncertainties associated with knowledge of global distribution of tropical rainfall was decreased from 50% to 25% on the way to 10% by FY 2001. TRMM precipitation data were also used to demonstrate improvements in hurricane track forecasting over the U.S. when they were incorporated into atmosphere assimilation models. This information will provide a scientific basis for quantitative precipitation forecasts in tropical regions, a principal scientific objective of global climate change research and the U.S. Weather Research Program.

The NASA Seasonal to Inter-annual Prediction Project (NSIPP) has implemented a baseline coupled climate prediction system, consisting of the Aries global atmospheric model coupled to the Poseidon global ocean model. Experimental forecasts are able to predict tropical Pacific Sea-Surface Temperatures (SSTs) up to six months in advance. The ocean model has been successfully initialized using Special Sensor Microwave/Imager (SSM/I) surface winds data, a combination of in situ and remotely measured SST's, and sub-surface temperature data from TOGA Atmosphere-Ocean (TAO) moorings. Assimilation of sea surface height data from Topex/Poseidon is now underway and will be used for the initialization of coupled forecast experiments. Future tests will include the use of QuikScat surface winds in the ocean initialization procedure. The Mosaic catchment land surface model has been developed and shown to yield improved representations of the effects of sub-grid-scale topographic variability and of soil physics in meteorological models. Knowledge of soil moisture has been shown to lend to a significant improvement in predictability of precipitation over much of the U.S. in summer. A simple three-layer snow model has been added. The snow model accounts for snow melting and refreezing, dynamic changes in snow density snow insulating properties, and other physics relevant to the growth and ablation of the snow pack. This information will provide improved seasonal predictions of changes in weather patterns associated with the El Nino cycle, and changes in land surface hydrology.

Plans

In FY 2000, efforts will focus on the development/improvement of methods to couple state-of-art land surface and sea ice models to a global coupled ocean-atmosphere model and use this to predict the regional climatic consequences of El Niño or La Niña occurrence in the tropical Pacific. The ultimate goal is to develop a capability to significantly improve the prediction of seasonal-to-interannual climate variations and their regional climate consequences. An important emphasis will be on the implications of the major interannual variations on the climate of North America. Measurements of the production and radiative properties of aerosols produced by biomass burning in Africa will be made as part of an international field experiment, the SAFARI-2000. The information obtained from this mission will assist in the interpretation of aerosol measurements made by instruments on NASA's Terra spacecraft was launched in December 1999, as well as other currently operating instruments. Biomass burning in Africa

contributes a significant component of the global atmospheric aerosols. This information will provide a quantitative understanding of the impact of fires on atmospheric radiation and climate.

ESE will establish a benchmark for global and regional rainfall measurements by combining TRMM measurements with measurements from other sources. Maps of the diurnal cycle of precipitation will be created for the first time. The existing ten-year data set will be combined with TRMM measurements to validate climate models and demonstrate the impact of rainfall on short-term weather forecasting.

Complete the collection of satellite data needed for the 17-year cloud climatology being developed under the International Satellite Cloud Climatology Project (ISCCP). Data will be used to improve the understanding and modeling of the role of clouds in climate. Since the representation of clouds constitutes one of the major areas of uncertainty of climate models, the ISCCP data will be crucial to evaluating the competing ideas about how to represent cloud processes in global models.

In FY 2001 ESE will continue to explore the dynamics of the global water cycle by developing, analyzing and documenting multi-year data sets. The program will help resolve the wide disparity of precipitation estimates that currently exist, thus improving our understanding of the global water cycle. TRMM will obtain accurate maps of the diurnal cycle of precipitation and, in conjunction with a 10+ year reanalysis of SSM/I data, set a benchmark for Tropical precipitation. In preparation for a future space-based measurement of soil moisture, the airborne platforms program will demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture. It is anticipated that this information will lead to reliable estimates of evaporation, precipitation, and the recycling of rainwater over continents.

ESE will also decrease the uncertainty in determinations of radiation forcing and feedback, and thereby increase accuracy in our knowledge of heating and cooling of the Earth's surface and its atmosphere. The program will continue the analysis of global measurements of the radiative properties of clouds and aerosol particles being made by the MODIS, the Multi-Angle Imaging Spectrometer (MISR), and the Clouds and Earth's Radiant Energy System (CERES) instruments on the EOS Terra satellite. ESE will continue to explain the dynamics of the global water cycle by building improved models and prediction capabilities. Improvements will be made to our current understanding of the large-scale effects of clouds in climate and the ability to model them will also improved through collection and processing of satellite data needed for the multi-decadal global cloud climatology being developed under the ISCCP. A decadal Surface Radiation Budget (SRB) climatology will be completed. These studies will serve as validation of parameterizations of Earth's radiative processes in models that simulate the cycling of fresh water through Earth's atmosphere and the transfer of visible and infrared radiation in the atmosphere. This information will provide a quantitative basis for estimating the components of the radiant energy budget of the Earth, and their impact on climate.

Climate Variability and Prediction: understanding, modeling and predicting near and long-term climate variability at global and regional scales

Climate is not perceived as a static property of the environment any more, but rather a dynamic state that is expected to evolve in the future. This research theme focuses on the modes of variability that involve in a fundamental way the dynamics of the slower components of the physical climate system, the ocean circulation and the mass balance of polar ice sheet. These components respond to disturbances with greater inertia, and therefore longer "memories", than the atmosphere. Currently ESE research seeks to; understand the mechanisms of climate variability and predict future transient variations, assess the response of the Earth

climate to changes in external forcing factors or surface boundary conditions, and assess the current mass balance of polar ice-sheets and potential future changes, including effects on sea level.

Accomplishments

The Goddard Institute for Space Studies (GISS) climate model studies have indicated the possible importance of stratospheric ozone processes for surface climate change, and thus the need for including the upper atmosphere in climate models. The climate model also reveals that increasing greenhouse gases amplify the "high" phase of the Arctic Oscillation, providing a plausible reason why Northern Hemisphere winter warming in recent years has been much larger over the continents than over the oceans. Additional model studies have been useful for quantifying and comparing the different natural and anthropogenic climate forcings that influence long-term climate change. A sophisticated ocean turbulence model has been added to the GISS climate model system. The ocean turbulence model breaks new ground in that it is the first to include salinity within a consistent theoretical framework. Also it is the first turbulence parameterization model to consistently represent vertical mixing throughout the whole ocean, from the strong mixing in the upper mixed layer to the weak mixing at depth. The models being developed thus have improved representation of physical processes and should thus provide more realistic simulation of future climate change allowing for improved climate assessment.

The Global Aerosol Climatology Project (GACP) is producing initial climatologies of aerosol optical thickness and particle size parameter using satellite measurements and transport model calculations. The initial satellite and model results are being intercompared for accuracy and precision. Analysis of field experiment measurements have been completed, data products are available from the LaRC DAAC and science results are in publication in special issues of Journal of Geophysical Research. Results of Aerosol Robotic Network (AERONET) analyses (aerosol optical thickness and size parameter) are available on the World Wide Web, for use in scientific research within 24 hours of acquisition. These data are incorporated in climate and atmospheric chemistry models to improve their ability to simulate environmental change in response to change in aerosol loading.

Significant progress was made in studies of ice-covered regions of the Earth. A larger, statistically significant decrease in the amount of sea ice in the Northern Hemisphere over the past 20 years has been documented. Changes in the height of ice in Greenland over a several year period have been demonstrated using airborne measurements. A high-resolution model of the structure of ice in Antarctica has been created using data from the Canadian RADARSAT mission. These data show the existence of "ice streams" that transport ice more rapidly than previously expected. This motion has the potential to lead to more rapid reduction of ice amounts in a warming environment than had been previously assumed potentially accelerating the rate of sea level rise.

The QuikScat spacecraft, launched in FY 1999, joins TRMM and the Ocean Topography Experiment/Poseidon (TOPEX/Poseidon), to form a powerful suite of space-based observational asset to track phenomena such as El Niño/La Nina. QuikScat replaced the NASA Scatterometer instrument that was lost in the failure of Japan's ADEOS spacecraft launched in 1997. With QuikScat ESE began measurement of sea-surface wind speed and direction at a spatial resolution of 25km resolution over at least 93 percent of the ice-free global oceans every two days. This represents a resolution increase of a factor of two, and a 15 percent increase in coverage over previous measurements. Data from this mission will be used to improve the short-term weather forecasts.

Plans

There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like the El Niño events. In FY 2000, through the Terra instruments, we will begin conducting daily observations of cloud properties such as extent, height, optical thickness, and particle size. We will map aerosol formation, distribution properties and sinks over the land and oceans. In addition, we will achieve a substantial reduction in the uncertainty in components of the Earth's radiation balance (e.g. improved angular models leading to an estimated error reduction in regional-scale monthly-average net radiation of about 50%). Besides improving our basic understanding of the distribution of these parameter fields the resulting data will be used in evaluation of climate change models.

Efforts in FY 2000 include analysis of the CERES measurements to achieve a further reduction in the uncertainty in the determination of top-of-the-atmosphere radiative fluxes through the integration of measurements provided by the CERES instruments on TRMM and Terra. The data provide a critical test of the radiative aspects of climate change models.

The first detailed estimates of thickening/thinning rates for all the major ice-drainage basins of the Greenland ice sheet, derived from repeated airborne laser-altimetry surveys will be published. These measurements also represent a baseline data set for comparison with early measurements to be made by ICESat, to be launched in 2001. The airborne project for mapping of layers within the Greenland ice sheet to decipher the impact of past climate variation on polar regions will be initiated. Through a RADARSAT repeat of the Antarctic Mapping Mission a second set of high-resolution radar data will facilitate a comparison of baseline data to identify changes on the ice sheet. The data obtained will help assess possible ice sheet changes so that their effect on sea level change can be examined.

The launch of the NASA-CNES Jason-1 mission in FY 2000 will enable a factor-of-four improvement in accuracy in measuring ocean basin-scale sea-level variability versus TOPEX/Poseidon. Additionally ESE will generate the first basin-scale high-resolution estimate of the state of the Pacific Ocean as part of the international Global Ocean Data Assimilation Experiment (GODAE). This information will serve as input for seasonal weather forecasting models and should lead to improved representation of the physical coupling between the oceans and the atmosphere in climate models.

With the launch of EOS ACRIMSAT, continual long-term, continuity in measuring the total solar irradiance will be assured. It will provide a total solar irradiance data set for the complete period of maximum solar activity (2000 – 2005). The absolute accuracy of this data set will be equal to or better than previous space-based measurements, about 1000 ppm, and will provide a quantitative understanding of the solar forcing of Earth's climate. This information will be used as input to climate change models so that the effect of the variability in this natural external forcing of the climate can be simulated.

ESE will continue the development of the global aerosol climatology data set and analysis of this climatology in climate models. Data will be available in the GSFC DAAC. This effort will help continue to improve the design and sophistication of a global climate system model that will contribute to the First National Assessment of the Potential Consequences of Climate Variability and Change. This information will bring a new perspective to our understanding of the processes driving our climate.

In FY 2001 ESE will continue to explore the dynamics of long-term climate variability by developing, analyzing, and documenting multi-year data sets. In FY 2001, ESE will complete detailed mapping of thinning/thickening rates for all major ice catchments on

the Greenland Ice Sheet from airborne laser altimeter data. This will serve as a baseline for future satellite-based surveys, to determine the behavior of the ice sheet and its influence on global sea level change. Continue the measurement of ocean basin-scale sea-level variability with Jason-1 satellite data. ESE will also continue, through ACRIMSAT the high precision, multi-decadal record of total solar irradiance measurements towards capturing three solar cycles. This information will provide a quantitative basis for assessing the contribution of solar variability to on-going climate change.

ESE will continue to explain the dynamics of long-term climate variability by building improved models and prediction capabilities. Observational capability will be enhanced through development and demonstration of a technique to measure and diagnose open ocean variations in salinity by 0.1 psu from airborne platforms. Salinity is a critical factor in forcing ocean circulation. Work will be done to improve understanding and modeling of the aerosol radiative forcing of climate and its anthropogenic component as needed for the 20-year climatology of aerosol optical thickness and particle size under the GACP. This will be accomplished through the development and validation of aerosol retrieval, cloud-screening algorithms, processing of satellite data and transport model evaluations. We will demonstrate the experimental seasonal climate predictions by using next-generation super computing systems and new-coupled air-ocean-land-ice models. This demonstration will incorporate all available satellite observations (e.g., TOPEX, Jason, Seawinds, TRMM, SeaWifs, MODIS) of key ocean surface parameters such as wind vectors and altimetry. The accuracy of realistically forced long-term climate models will be enhanced to simulate observed global temperature research. Particular emphasis will be placed on the seasonal and spatial variability over the last 40 years to develop improved confidence in ability of models used for climate prediction. This information will provide the scientific basis for reliable assessments of potential future changes in global and regional climates.

Atmospheric Chemistry: monitoring and predicting how atmospheric composition is changing in response to natural and human-induced factors

Atmospheric change is the result of strongly interactive chemical and physical processes. Chemistry plays a role in determining weather and climate, while the physics and dynamics of the atmosphere influence chemical processes and composition. The goals of the atmospheric Chemistry research program are to measure and understand how atmospheric composition is changing in response to natural and anthropogenic forcings, and enable accurate prediction of future changes in ozone and surface ultraviolet radiation, climate forcing factors, and global pollution.

Accomplishments

Fulfilling its Congressional mandate for upper atmosphere and ozone research, ESE has acquired a twenty-year data set on ozone concentration and distribution. ESE continues to explore the chemical processes of ozone destruction and replenishment in the stratosphere, and is beginning to probe the complex chemistry of the troposphere, the lower portion of the atmosphere in which we live. ESE employs this capability to make essential contributions to international scientific assessments of ozone by the World Meteorological Organization. NASA's contributions in this area are to develop and operate space-, airborne-, and ground-based instruments that will map the fluctuations in ozone, aerosols and related constituent gases in the atmosphere, as well as develop models that can be used to simulate prior and future evolution of atmospheric composition. These models will provide added insight into changes in the atmosphere and potentially its influence on climate.

In FY 1999 NASA has utilized an integrated program of space, aircraft, balloon, ground-based and laboratory measurements, along with global and process scale modeling activities to achieve a number of significant accomplishments toward understanding the causes of variation in ozone concentrations and distribution in the upper and lower atmosphere. This information will provide improved knowledge of chemical and aerosol processes incorporated in assessment models.

In FY 1999 ground-based, balloon-based, and airborne in situ and remote-sensing measurements continued to show evidence that the halogen burden in the lower atmosphere is beginning to decline in response to actions taken in response to the Montreal Protocol. Global measurements from the Upper Atmosphere Research Satellite (UARS) have yielded the first evidence of this response in the upper stratosphere. This information demonstrates consistency in our knowledge of the chlorine chemistry of the stratosphere and helps lend further credence to the models used to assess future atmospheric chemical change.

The Total Ozone Mapping Spectrometer (TOMS) continues to provide the global view of how ozone is responding to these reductions in atmospheric halogen burden, and is providing new data products such as tropospheric ozone columns. The Southern Hemisphere Additional Ozonesonde network (SHADOZ) and the field measurements phase of the Pacific Exploratory Mission (PEM-Tropics-B) provided additional advances in tropospheric chemistry. Satellite data from the second Stratospheric Aerosol and Gas Experiment (SAGE II) and lidar data have shown that the distribution of stratospheric aerosol amounts are as low or lower than they have been since accurate global measurements began. In response to the launch delays for the SAGE III instrument due to problems experienced by our Russian partner, the ESE supported the continued operation and data processing for the DOD Polar Ozone and Aerosol Mission (POAM) satellite instrument, thereby providing high latitude data on distribution of ozone, aerosols, water vapor, and nitrogen dioxide. The SAGE and POAM data will help improve our knowledge of stratospheric aerosols under these new background conditions and their contribution to atmospheric chemical change.

Three new data products were produced from TOMS data including surface ultraviolet (UV), tropospheric ozone column amounts and UV absorbing tropospheric aerosols. Progress was made on understanding Solar backscatter Ultraviolet (SBUV2) characteristics. Improvements to the calibration correction, the nonlinearity corrections for the Photomultiplier Tube and understanding the instrument's orbital hysteresis are complete, and reanalysis is taking place. Re-analysis was applied to the intercalibration and gap filling of the TOMS data. This re-analysis has revealed seasonal features that require further investigation prior to final release of the new 20-year ozone data set. This data set represents one of the primary long term records of Earth system change and is used in the evaluation of atmospheric chemistry models as well as input to climate change models.

The detailed multi-aircraft study of troposphere chemistry over the tropical Pacific Ocean continued, including the contribution of long-range transport of air from South America and Africa to otherwise unpolluted areas. The field measurements phase of PEM-Tropics-B (rainy season) was completed with an improved payload that has resulted from an initiative to develop a smaller, lighter payload with equal or better performance than PEM-Tropics A (dry season). The results were released in October 1999. The results will improve our knowledge of the factors that govern the chemical composition (pollutant levels of areas of the atmosphere previously thought to be little subject to human influence).

Surface levels of chlorine- and bromine-containing chemical compounds addressed under the Montreal Protocol were measured. This documents the decreasing concentrations of the regulated compounds and the rising concentrations of their replacements to quantify the decrease in total halogen abundance in the lower atmosphere. The analyses were incorporated in the United Nations Environment Program/World Meteorological Organization (UNEP/WMO) "Assessment of Ozone Depletion 1998" Monitoring Project Report #44, that was completed in FY 1999. These data help test international compliance with the Montreal Protocol and support the further evaluation of the assessment models used in the study of ozone depletion.

Plans

Efforts in FY 2000 will implement the SAGE III Ozone Loss and Validation Experiment (SOLVE). Measurements will be made during the timeframe of October 1999 - March 2000 in the Arctic and high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as balloon platforms. The mission will also acquire correlative data needed to validate the SAGE III satellite measurements that will be used to quantitatively assess high-latitude ozone loss. In FY 2001 comprehensive analysis of the data will provide increased prognostic ability for Northern Hemisphere high latitude ozone loss in an atmosphere perturbed by an increased abundance of greenhouse gases. The improved models that will be developed in response to these data will be used in assessments of future ozone changes and their impact on climate.

The initial analysis and publication of the PEM-Tropics-B field experiment will be complete by the end of FY 2000. This information will provide improved knowledge of the processes by which trace gases and aerosols can be transported over long distances from source regions to otherwise less polluted regions of the atmosphere.

The ESE will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally distributed measurements of the surface level concentrations of long-lived industrially produced trace gases and other biogenically-produced gases such as methane and nitrous oxide. In addition, we will complete acquisition of first ever-global climatology of vertical profiles of carbon monoxide (CO) to improve knowledge of its surface sources, photochemical destruction, and how it is transported by tropospheric wind systems (based on MOPITT data from Terra). This will lead in 2001 to improved assessment of the role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane. Detailed validation of the MOPITT data product will be carried out with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments. The data will improve our understanding of the contribution of fires and fossil fuel combustion to global pollution and to better assess our knowledge of the sources of methane and thus its potential contribution to atmospheric and chemical climate change.

In FY 2001 ESE will provide continuity of multi-decadal total ozone concentration measurements using the existing Earth Probe TOMS satellite instrument and its successor the QuikToms spacecraft, planned for launch late FY 2000, and related space and ground based total ozone measurements. This will aid in characterization of long-term evolution of ozone and enable assessment of ozone recovery processes, and in assessment of the adequacy of current international regulations to protect the ozone layer in a changing climate.

We will continue to monitor atmospheric concentrations of chlorofluorocarbons (CFCs) and new industrial substitutes through implementation of gas chromatographic mass spectrometric instrumentation within the Advanced Global Atmospheric Gases Experiment (AGAGE) in-situ network. This will be done to assess international compliance with the Montreal Protocol and provide a firm basis on which to assess their contribution to ozone depletion and climate change. A comprchensive climatology of high-resolution ozone vertical distribution in the southern subtropics will be developed (upper troposphere and lower stratosphere). The climatology will be based on a complete first year of data from SHADOZ network. Tropospheric ozone values obtained from TOMS data will be compared with integrated tropospheric ozone values from SHADOZ to assess the accuracy of the TOMS tropospheric ozone algorithms. We will characterize long-term (multi-decade) evolution and interannual variability in high latitude ozone, aerosol, and polar stratospheric cloud profiles through combination of SAGE III data with those from previous instruments such as SAM, SAM II, SAGE, SAGE II, and POAM. These data will improve our knowledge of the role which ozone changes may play in contributing to climate change as well as the way in which ozone concentrations may respond to climate variation.

The time evolution of ozone and aerosol fields over the sunlit Earth will be directly measured for the first time in FY 2001 using observations from the Earth Polychromatic Imaging Camera (EPIC) instrument on the Triana spacecraft. These Triana observations will also allow the first daily diurnally integrated estimates of surface UV radiation based on satellite data of overlying ozone, aerosol, and cloud distributions, which will be provided to scientists interested in ecological and health effects of surface UV radiation.

ESE will continue to explain the dynamics of atmospheric composition by building improved models and prediction capabilities. In FY 2001 stratospheric model development will be focussed on increased prognostic ability for Northern hemisphere high latitude ozone loss in an atmosphere perturbed by and increased abundance of greenhouse gases through comprehensive analysis of data from the SOLVE coordinated field experiment. Also, ESE will provide improved assessment of the role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane using data from the MOPITT instrument aboard the EOS-Terra satellite. In addition, work will be done to characterize atmospheric plume flowing out of East Asia, its evolution as it transits eastward over the Pacific Ocean, and its contribution to global atmospheric chemical composition. In FY 2001, a major multi-aircraft campaign known as the Transport and Chemistry near the Equator over the Pacific (TRACE-P) is planned for East Asia to help assess the effects of outflow of trace gases and particulates into the Western Pacific Ocean. This mission will be planned to incorporate the use and analysis of satellite data and atmospheric models, and improve our understanding of the way in which changes in global atmospheric chemistry affect and are effected by changes in regional air quality.

Solid Earth and Natural Hazards (Solid Earth portion): discovering the nature and processes of the Earth's dynamic interior and crust to better prepare for natural hazards.

The resources for this theme area are shared between Earth Science Program Science (Solid Earth) and the Applications, Commercialization and Education program (Natural Hazards). Since the Solid Earth activity is more Science related it is managed more appropriately with ESE's other basic Science Research activities. The Natural Hazards theme area is better served as part of the Applications Research program due to its relevance to the ACE initiatives focussed on bringing scientific results to a more immediate practical use.

The long-standing Earth science research program in fundamental solid Earth science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquakes, volcanic eruptions, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

Accomplishments

In FY 1999, the Shuttle Radar Topography Mission (SRTM) instrument was developed to create a near-global high-resolution digital elevation topographic map of the world. The instrument was integrated on the Endeavor and is scheduled for launch in early 2000. The data from the SRTM will allow scientists in federal, state and local agencies, and academia to study the terrain for basic research such as ecology, geology, geodynamics, hydrology and atmosphere modeling. This information provides a multi-disciplinary tool for assessing vulnerability to natural hazards and sensitivity to local environmental changes.

During 1999, the Global Positioning System (GPS) array in Southern California monitored crustal deformation, recording and transmitting on a daily basis. Data and solutions for site velocities and time series of site positions were made available on the internet. These measurements clearly identified discontinuities in the direction and magnitude of crustal motion across fault lines. Federal, state and local agencies and companies are using the Southern California Integrated GPS Network (SCIGN) data to study ground deformation related to earthquakes, and to continually assess the vulnerability and risk of earthquakes to the region. Local agencies and surveying groups are also using SCIGN data for their spatial reference system and beginning to support the operations of the array. This information will provide a scientific basis for understanding the earthquake cycle and laying out the foundation for earthquake prediction.

The coupling of the dynamics of the solid earth to that of the atmosphere was demonstrated with the use of data from the very Long Baseline Interferometry (VLBI) network. In particular, variations in the length of daylight were highly correlated with the dynamics of the ocean-atmosphere system associated with the El Nino Southern Oscillation.

As part of the effort to test improved algorithms for sounding the atmosphere with occulted GPS signals, the Oersted spacecraft is successfully obtaining precision GPS data and occultations for six out of every 27 hours. The JPL project team is analyzing this data, and the results will be published in science literature. This information will provide the basis for assessing the effectiveness of this new observing technique for climate change studies and weather prediction.

Plans

In FY 2000, we will continue to use the Southern California GPS (SCGPS) array data to develop an understanding of the connection between seismic risk and crustal strain leading to earthquakes. This will be done by monitoring the movement of the ground over time to detect strain buildup or subsidence, and installing another 100 of the SCGPS array of precision GPS locators/receivers for monitoring strain accumulation.

Research in FY 2000 will continue to develop models to use static and time-varying gravity observations (in conjunction with the Challenging Mini-satellite Payload (CHAMP) and GRACE Missions) to better understand variations in the Earth's gravity field estimate water storage changes to provide data to hydrologists on water mass expansion and climate variations. In addition, we will continue observational efforts using Satellite Laser Ranging and Global GPS to maintain the International Terrestrial Reference System as a reference for other geodetic observations that include gravity variations, sea level observations, ground deformation observations and other geodetic observations of the earth. This information will maintain and improve the determination of the global geodetic reference frame for satellite navigation systems and GPS-based observations.

The SRTM instrument will be launched in early FY-2000, and will gather topographic data. During FY 2000 and through FY 2001, we will conduct analyses of the near-global SRTM 30 meter topographic data for global geologic and geomorphic process studies. This will provide the first continuous digital elevation model of 80% of the Earth's surface for better understanding the composition and processes on the Earth's surface for scientific understanding and urban and aircraft flight planning purposes.

In FY 2001 ESE will continue to explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets. We will use the daily orbit solutions for all GPS constellation satellites as a basis for cm-level orbit determinations and mm-level ground-based GPS positioning and navigation. This will enable near-real-time assessment of ground deformation for disaster response after earthquakes, and swelling of the ground as a precursor to explosive volcanic eruptions.

ESE will continue to explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. This will be accomplished by improving our understanding of geodynamic processes through the completion of the VLBI Mark IV Correlator upgrade which will result in increased observation frequency, faster data processing and lower operational costs. ESE will also complete the second phase of SCIGN array of 250 precision GPS locators/receivers installation. This information will improve our ability to monitor crustal movements.

EOS Science

In 1988, NASA issued an Announcement of Opportunity (AO) for the selection of instruments, science teams and interdisciplinary investigations in support of the Earth Observing System (EOS). The initial EOS/IDS investigations were selected in 1990 to conduct basic research, develop methods and models for analysis of EOS observations, develop and refine models of Earth system processes, and forge new alliances among scientific disciplines fostering a new perspective into how the Earth functions as an integrated system. These investigations involved analysis of data from EOS precursor missions (e.g. TRMM, Landsat-7) and international instruments (e.g. ADEOS, ERS, Radarsat) and in situ observations, with results being made available through EOSDIS to enhance broad participation by the science community at large. Subsequently, additional IDS investigations were selected bringing the total to 71.

Plans

In FY2000 the first round of EOS interdisciplinary science investigations will be essentially completed. These consist of the historical interdisciplinary investigations (10-year grants), the subsequent interdisciplinary investigations (3-year grants), and the investigations associated with the Joint Global Flux Program (JGOFS), (also 3 year grants). The entire interdisciplinary science investigations program was re-competed in FY1999 through the AO process, with new selections planned for early FY2000 and FY2001. This series of investigations will capitalize on exploitation of the data to be provided by Landsat 7 and QuikScat as well as the Terra (EOS AM) spacecraft, launched in December 1999, and the Aqua (EOS PM) spacecraft scheduled for launch in 2000.

Mission Science Teams and Guest Investigators

The mission science team/guest investigators program provide the opportunity for scientists from all institutions to participate in the analysis, verification, and utilization of data from NASA's currently operating space-based instruments. Funding provides for analyzing data from the UARS, TOPEX, Earth Radiation Budget Satellite (ERBS) and other space borne instruments such as Solar Backscatter Ultraviolet (SBUV/2), TOMS, QuikScat, and TRMM. The exploitation of UARS data still involves more than 100 investigators from the United States and many other countries, notably Canada, the United Kingdom, and France. Key TOMS and SBUV/2 participants include NOAA, Russia, and Japan. Key ERBS users include a diverse set of institutions including NOAA (NOAA manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography. The TOPEX users include France (shared in development of the mission), Japan, Australia, the United Kingdom, the Netherlands, Germany, Norway, and South Africa as well as JPL, GSFC, Columbia University, the University of Hawaii, the University of Texas, the University of Colorado, Oregon State University, Ohio State University, and the Massachusetts Institute of Technology. SeaStar/SeaWifs principal users include GSFC, the European community, Japan, Canada, and Australia and universities in Florida, Washington, California, Texas, Maryland, and Rhode Island. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study (JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research (SCOR) and the International Geosphere-Biosphere Program (IGBP). Active international participation through the International Ocean Color Coordinating Group is carried out to help synthesize data from the various space-based ocean color sensors of different nations that are currently operating. NSCAT investigators include scientists from JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS-1 spacecraft), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with Japan to measure tropical precipitation from a low inclination orbit. Participants in the analysis of Shuttle Imaging Radar/X-Band Synthetic

Aperture Radar (SIR-C/X-SAR) data, in addition to JPL, represent nations in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

In a number of cases, data from one instrument have been shown to have use in other applications, and the mission analysis programs actively encourage such uses. Mission science teams are typically competed triennially. The budget for these teams is expected to begin to increase significantly in FY 2001, as funds that were provided to the EOS instrument science teams for algorithm development will be converted to mission analysis following the launch of the relevant missions and spacecraft.

Airborne Science and Applications

In FY 1999, twelve major campaigns were flown, over 1470 flight hours. The campaigns produced science data for rainfall, land-cover/land-use and atmospheric chemistry. Six major campaigns are scheduled for FY 2000, over 1400 flight hours. The core NASA Earth science aircraft fleet is fully subscribed, therefore lease, or other acquisition method, will again be used to fulfill the requirements which cannot be met by the core fleet. The campaigns will return scientific data on arctic ice and meltponds, atmospheric chemistry, land-cover/land-use, and salinity.

Uncrewed Aerial Vehicles (UAVs)

The UAV science project will augment the Earth science airborne project. Initially it will make *in situ* and remote-sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation. Initial work in the UAV science was to develop and test a payload of instruments suitable for study of the radiation field in the upper troposphere and lower stratosphere as well as the relationship between atmospheric physical and chemical parameters and the radiation field. The centerpiece of this payload is a newly constructed high-resolution infrared and far infrared radiometer. The radiometer has been tested on the ER-2 and has been flown on the ER-2 together with several other instruments making measurements of atmospheric physical and chemical properties in order to provide enough data to test the retrieval algorithms used to interpret data from the radiometer. Both series of test flights were carried out from the Dryden Flight Research Center in California.

Accomplishments

In FY 1999, a stratospheric chemistry instrument suitable for flight on a UAV (small, lightweight and autonomous) was developed and is being flown to verify its performance in the SOLVE mission. Assistance was given to the flight demonstration program to increase UAV heritage to improve user confidence in the UAV as a viable platform

Plans

In FY 2000, the plan is to fly the radiometer and a small number of other instruments on a UAV. The UAV must have sufficient flight heritage and instrument modifications will be necessary to mate with the selected UAV. For FY 2000 and beyond, a NRA will be issued soliciting UAV missions supporting the science and applications goals of the ESE. The NRA will solicit 2-3 UAV-based Science Demonstration missions in the PI-mode. In FY 2001, the UAV-based Science Demonstration Program will be underway with 2-3 missions preparing payloads for flight. These missions which to be selected should make use of the unique capabilities of UAVs and help improve our knowledge of one or more of the components of the Earth system.

Information Systems

The Earth science information systems project will continue to provide a balanced computational environment for NASA science researchers primarily through the facilities housed at GSFC and JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the project's requirements in the strategic planning of new computational technologies. Recently initiated cooperative agreements will allow the development of supercomputer applications 10 times faster than today, providing the computational studies necessary to mesh with NASA's observational and theoretical projects.

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

APPLICATIONS, COMMERCIALIZATION, AND EDUCATION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Research and Analysis – Applications	[25,600]	[32,769]	21,200
Commercial Remote Sensing	[38,100]	[30,435]	31,900
Education	[11,900]	[15,200]	16,100
EOS Fellowships and New Investigators	[4,800]	[5,300]	7,000
Education and outreach	[2,100]	[4,900]	4,100
Global Observations to Benefit the Environment	[5,000]	[5,000]	5,000
Subtotal Without Education Agency Investment	[75,600]	[78,404]	69,200
Education Agency Investment	[7,300]	[7,300]	--
Total	[82,900]	[85,704]	69,200

Note: Earth Science Program Science in FY01 has been broken out to reflect the distinction between the Research Program and the Applications, Commercialization and Education (ACE) Program. These changes are reflected in realignment of the following areas to the ACE program: applications portion of R&A, the fellowships portion of EOS Science, and the Commercial Remote Sensing Program.

PROGRAM GOALS

The goal for the Applications, Commercialization and Education program is to Expand and accelerate the realization of economic and societal benefits from Earth science, information and technology. This is to be done by enabling productive use of Earth system science results, data and technology in the public and private sectors, supporting the development of a robust commercial remote sensing industry, and increasing public understanding of and involvement in Earth system science through formal and informal educational opportunities.

STRATEGY FOR ACHIEVING GOALS

The applications Research and Analysis (R&A) effort is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academies of Sciences. The applications R&A consists of one of the five management areas: the Natural Hazards portion of Solid Earth and Natural hazards.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Natural hazards research is exploring the use of science, technology, and remote sensing observations for the assessment of vulnerability to natural hazards and mitigation of natural hazards including earthquakes, volcanic eruptions, landslides, drought and flood consequences.

The Commercial Remote Sensing Program (CRSP) funds cooperative efforts with industrial, university, and state and local government partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the demonstration of usable, customer-defined information products. Industry and others will make significant co-investments, funding or in-kind contributions to the co-developed projects at about an equal level with NASA.

The Education program seeks to increase public understanding of and involvement in Earth system science through formal and informal educational opportunities. This activity ranges from graduate student participation in the Earth System Science Fellowship (ESSF) program and new faculty member participation through the New Investigator Program (NIP) to participation in the Global Observations to Benefit the Environment (GLOBE) program. The goal of the GLOBE program is to link scientific discovery with the education process in the study of the Earth as an integrated system. The objective is to bring school children, teachers, and scientists together to: (1) enhance environmental awareness of individuals throughout the world; (2) contribute to scientific understanding of the Earth; and (3) help all students reach higher levels of achievement in science and mathematics.

The GLOBE program is an interagency activity led by NOAA in which NASA has a key role. It involves students (kindergarten through twelfth grade or equivalent) in schools throughout the world, their teachers and the research community. Participating schools are making core sets of GLOBE measurements using GLOBE instruments and procedures under the guidance of GLOBE-trained teachers. The results from all over the world are reported into a central data processing facility. The students then receive feedback and use GLOBE educational materials to understand the compiled results and do their own analyses of the data. The program is designed to be international in scope, involving students, educators and researchers from all over the world. By using

the Internet to link the schools together, a sharing of discoveries and analysis is encouraged that should result in awareness beyond just the local community. This program also seeks to contribute to the scientific understanding of the Earth. International environmental scientists have been involved from the beginning of the program to select a set of significant scientific measurements that can be made by students and define the experimental procedures and data reporting protocols for each.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

Natural hazards only	FY 1999 Actual	FY 2000 Estimate	FY 2001 Estimate
Number of principal investigators	15	15	15
Number of research tasks under way	16	16	20
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	.5	.5	1
Number proposals received	53	60	70
Number of proposals rated very good to excellent	17	20	20
Number of proposals selected	14	15	15
Time to process proposal (selection through obligation)	45 days	30 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	87%/91%	100%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

* Estimate revised due to consolidation of solicitations.

SCHEDULE AND OUTPUTS FOR GLOBE

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Revised	Plan
Number of Participating Schools	8,000	7,767	10,500	10,300	10,500
Number of Participating Teachers (Revised goal for FY 2000 and beyond)		11,300	12,000		13,800

ACCOMPLISHMENTS AND PROPOSED RESULTS

RESEARCH AND ANALYSIS - Applications

In FY 1999, continuing into FY 2000 and FY 2001, the following are significant accomplishments in the area of Natural Hazards and applications research.

Solid Earth and Natural Hazards (Natural Hazards portion): discovering the nature and processes of the Earth's dynamic interior and crust to better prepare for natural hazards

The long-standing Earth science research program in fundamental solid Earth science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquakes, volcanic eruptions, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

Accomplishments

In FY 1999, the Shuttle Radar Topography Mission (SRTM) instrument was developed. This instrument will enable the creation of a near-global high-resolution digital elevation topographic map of the world. The instrument was integrated on the Endeavor and is scheduled for launch in early 2000. The information from this mission will be used to produce one of the most comprehensive and accurate maps of the Earth ever assembled, offering a number of applications for data products and science including: geology, ecology, geology, geodynamics, hydrology, volcano monitoring, flood inundation modeling and atmosphere modeling, as well as applications in urban and infrastructure planning, and disaster management.

During 1999, the Global Positioning System (GPS) array in Southern California monitored crustal deformation, recording and transmitting on a daily basis. Data and solutions for site velocities and time series of site positions were made available on the internet. These measurements clearly identified discontinuities in the direction and magnitude of crustal motion across fault lines. Federal, state and local agencies and companies are using the Southern California Integrated GPS Network (SCIGN) data to study ground deformation related to earthquakes, and to continually assess the vulnerability and risk of earthquakes to the region. Local agencies and surveying groups are also using SCIGN data for their spatial reference system and beginning to support the operations of the array.

Plans

In FY 2000, we will continue to use the Southern California GPS (SCGPS) array data to monitor the movement of the ground over time to detect strain buildup or subsidence, and installing another 100 of the SCGPS array of precision GPS locators/receivers for monitoring strain accumulation. This information will help to develop an understanding of the connection between seismic risk and crustal strain leading to earthquakes.

Natural hazards research in FY 2000 will continue to study flooding and floodplain processes, process and distribute imagery of current flooding for broad use in flood damage assessment and assessment of accuracy of flood plain maps comparing current flood insurance maps. In this regard, we have partnered with the Federal Emergency Management Administration (FEMA) to evaluate and demonstrate the utility of remote sensing data for improved, faster and less costly flood plain mapping.

The SRTM instrument will be launched in early FY 2000, and will gather topographic data. During FY 2000 and through FY 2001, we will conduct analyses of the near-global SRTM 30 meter topographic data for global geologic and geomorphic process studies, comparative analysis, improved mapping of terrain features such as floodplains, and input to models for improvement of assessment of natural hazards. This will help in understanding the risk of natural disasters in developed areas and areas proposed for development to help better assess the risk of floods in developed areas and areas proposed for development.

In FY 2000, ESE will develop an automatic volcano eruption detection procedure using EOS Terra data sets that will automatically detect eruptions and monitor and track plumes. These procedures will be infused into ongoing efforts with the Federal Aviation Administration (FAA) for use in aircraft routing and warning systems. This information will help promote safe air travel.

ESE will continue to explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. This will be accomplished by improving our understanding of geodynamic processes through the completion of the VLBI Mark IV Correlator upgrade which will result in increased observation frequency, faster data processing and lower operational costs. ESE will also complete the second phase of SCIGN array of 250 precision GPS locators/receivers installation. This information will help to better assess the vulnerability and risk of earthquakes.

RESEARCH AND ANLAYSIS -- APPLICATIONS

The goal of the Earth Science Applications Research Program (ESARP) is to demonstrate the productive use of ESE science and technology in the public and private sectors in response to user needs. To achieve the goal, the ESARP works with non-NASA public and private partners to demonstrate Earth Science results, data and technology to a broad range of users for near-term practical applications.

The elements of ESARP that contribute to this goal are as follows:

1. Regional Earth Science Application Centers (RESACs): Help state and local government agencies and private industry understand the potential impact of climate change on agriculture, forest growth and health, wildfire hazard and watershed and coastal management. This information will help government agencies and commercial enterprises make informed land use decisions.

2. Joint projects with the Department of Agriculture: NASA is assisting DOA develop new approaches to the use of remote sensing in agriculture. The benefit of this program will be, among other things, more efficient and less polluting agriculture. For example, NASA is working with grape growers in California developing ways they can use high resolution remote sensing data to identify grapes ready for harvest, and radar data to gauge soil moisture and improve irrigation efficiency both procedures will have direct impact on vineyard efficiency and profit.

3. Earth Science Information Partnerships (ESIPs): The ESIPs are focused on using data from NASA's Earth Observation System in innovative ways, from improving the accuracy and timeliness of weather reports to emergency services. These partnerships will, among other things, understand weather phenomena and how those phenomena affect them, and assist agencies responsible for emergency services distribute better information faster to representatives in the field and to the public.

4. State and local programs: ESARP is working directly with state and local governments to help them realize the potential information content of NASA data. These projects will help state and local agencies acquire information at lower cost and with greater accuracy than ever before. The projects will also help state and local agencies make data and information available to the public faster and at lower cost.

Accomplishments

In FY 1999, ESARP initiated seven integrated Regional Earth science Applications Centers (RESACs) designed to apply remote sensing and related technologies to problems of regional significance and conduct region specific assessments. The RESACs are addressing problems such as forest growth and health, precision agriculture, land cover and land use mapping and inventory, water resources management, rangeland quality assessment, fire hazard management, integrated watershed and coastal management, assessment of long-term agricultural productivity and sustainability. The outcome of the RESACs will be an enhanced knowledge of potential regional consequences of climate change and variability by regional stakeholders such as state and local governments and private industry. This knowledge will lead to practical advances in the management of regional resources. These advances will be accomplished through regional applications research projects resulting in improved inventories of forest growth, more accurate mapping of land use and land cover, improved assessments of rangeland quality and long-term agricultural productivity, integrated regional management of hydrologic and coastal resources, and reduced risk of loss due to fire resulting in millions of dollars of savings to society.

In addition, ESARP jointly initiated with the United States Department of Agriculture (USDA) thirteen new projects to develop and demonstrate original and improved applications. These projects are in the areas of vegetation mapping and monitoring, risk and damage assessment; and resource management and precision agriculture. Additionally, ESARP and USDA partnered on three pilot projects leveraging the existing successful Land Grant and Space Grant networks into a cooperative NASA ESE-Space Grant/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology (i.e., remote sensing, Geographic Information System (GIS), GPS). Both of these activities will extend ESE's science results and push the existing applications science envelope forward in partnership with USDA. The Alliance will use remote sensing, GIS, GPS and other geospatial technologies to improve the benefits of traditional university extension activities for the Nation's farmers. The outcome will result in the development and validation of at least two new data products for routine decision-making by user organizations in the area of improved knowledge of

capability and suitability of agricultural lands and increasingly efficient site specific agricultural techniques. The solicitation for cooperative Applications Research projects with state and local governments will also be completed and released.

In FY 1999, the Type 3 ESIPs (which were selected in late FY1998 as part of the EOSDIS Prototype Federation) focused on applications development and interactions with the potential broader user community. Examples of partner activities include NBC Channel 4 in Washington, D.C. (weather and news) which is developing (system specification completed) an integrated News and Weather Visualization System for use within NBC owned and operated television stations. The system is based on using public and private remotely sensed data that would be used to generate products that can be used on-air. Another example is the New Mexico Earth Data Analysis Center (EDAC) which is working with state, regional, and local problems. To date, they have worked with the New Mexico Land Office and Middle Rio Grande Council of Governments to develop baseline GIS databases and remote sensing applications for land economics and regional hydrology, and have developed a multimedia image sampler to introduce the broader user community to the types of data available for operation and commercial applications. A third partner, Reading Information Technology, Inc. is working to use remotely sensing data as part of a computerized decision support system to assist in determining sea conditions that would decrease shipping cost and determine "optimized" ship routing. To-date, they have established the research partnership with Canadian Steamship Lines (CSL) and have successfully established GIS software on both ship and shore including the vessels' GPS navigation.

As part of its program, ESARP has eleven cooperative projects that involve state and local governments as users in areas such as land use planning, land capability analysis, critical areas management, and water resources management resulting from the solicitation. These projects will result in improved decision support systems in areas of priority needs defined by state and local governments including: land use and land cover inventory; land capability/suitability analysis; critical areas management; water resources management; forest inventory; site and route selection; and emergency preparedness. At least 2 new satellite remote sensing based applications will be developed in these applications areas as a result of these agreements.

Plans

In FY2000, ESARP will initiate additional project activities with state and local governments. One pilot project, the Regional Applications Center for the Northeast (RACNE) will be established to investigate, develop and facilitate use of NASA and other remotely sensed data in Cayuga County, NY and will focus on the management of the 24 county watershed area of the New York Finger Lakes. The RACNE Pilot Project will also provide assistance to other localities in the Northeast, where local use of Geographic Information Technology (GIT) and financial resources appear to be more limited. An additional project will utilize EOSDIS to establish a number of "datamarts" which will be directed at translating the ESE science data products and research results into decision-making information to address state and local everyday problems and needs.

Additionally, ESARP will build on the planning completed in FY1999 with the state and local community in FY1999 and will continue working with the National States Geographic Information Council (NSGIC), Western Governors Association (WGA), Aerospace States Association (ASA), National Association of Counties (NACO), Mid-America States Consortium and National Conference of State Legislatures (NCSL) to plan a set of Applications Research Program demonstrations that will be dedicated to the needs of state and local government resource manages and policy-makers for initiation in FY2001. In FY 2000, ESARP will hold at least five regional workshops for the purpose of increase communication and expanding collaboration with and among the State and

Local government user communities. These workshops will begin the process of demonstrating ESE data products and science results to the state and local government community for their use in practical decision-making.

In FY 2000, the ESARP will also continue to demonstrate new applications through the existing ESIP, RESAC, NASA/USDA Cooperative Geospatial Technology Extensions, and Agriculture, Forestry and Range Resources NRA selected projects in areas such as precise agriculture, runoff contaminants from abandoned mines, range land quality assessment, identifying and managing fire hazards, integrated watershed and coastal management, improved impervious surface cover estimates, predictive soil modeling, forest structure determination, crop production/yield determination, and land cover/use mapping and change detection.

In FY2000, the Regional Applications Center (RAC) Program will also be continued through GSFC as a mechanism to extend the benefits of its information technology research to a broader user community. The RAC Program transfers information systems technologies to the outside community by merging NASA's innovations into a functional system provided to regional organizations along with the necessary technical assistance. The RACs serve to support the ESARP's objectives and goal of fostering the self-supporting use of environmental and Earth resource data by regional institutions including state and local governments, universities, consortia and commercial companies. Some examples of existing RACs include the Chesapeake Bay Technical Center of Excellence which is a partnership between 3DI Geographic Technologies, WYE Research Laboratory, University of Maryland-Eastern Shore, Washington College, Chesapeake College and the Talbot County, Maryland Chamber of Commerce directed at the Chesapeake Bay Watershed problems; and the University of Louisiana at Lafayette which supports the oil operations in the Gulf of Mexico and the State of Louisiana's emergency management needs relating to the oil production with remotely sensed data.

ESE will also support Digital Earth activities in FY2000 through funding of on-going Digital Earth technology development tasks, development and implementation of Digital Earth scenarios by the NASA field centers, and the drafting of a formal Digital Earth Program plan. On-going Digital Earth technology development activities include support for the Open GIS Consortium (OGC) - a government and private industry group developing standards and protocols for ready, on-line access to geo-spatial data, the Web Mapping Testbed (WMT) – a prototype system that tests server and client interoperability, and the Digital Earth Reference Model (DERM), a summary of the present state of Digital Earth technology. NASA field centers were solicited for scenarios to demonstrate the Digital Earth concept. Scenarios under development for demonstration by the end of this fiscal year include a Digital Earth "Portal" for museum display, and educational materials involving the interactive use of geo-spatial data. NASA, through code YO, maintains an active role in Digital Earth development through on-going coordination of the Interagency Digital Earth Working Group, (IDEW), and the NASA, through the Digital Earth Office (DEO) at GSFC is developing a formal Digital Earth Program plan that will be submitted for review this year.

COMMERCIAL REMOTE SENSING

The goal of the Commercial Remote Sensing Program (CRSP) is to accelerate the development of a preeminent U.S. remote sensing industry and link ESE scientists with the commercial remote sensing industry to develop mutually beneficial partnerships. To achieve this goal, the CRSP implements partnership programs that demonstrate joint development of technology and applications with private companies, agencies, and educational centers. Examples are the Scientific Data Buy (SDB) and the EOCAP Hyperspectral Initiative.

Accomplishments

In FY 1999, CRSP established over 100 partnerships in stimulating value added remote sensing product development, a 41% increase from 70 in FY 1998. These partnerships were established in areas of education, environmental quality, agriculture, health and safety, natural hazards, natural resources, and urban infrastructure, and will ultimately generate tangible services and products that benefit society. Examples include maximizing the capacity of waste disposal sites, and providing information to civil defense and insurance companies to lessen the loss of property resulting from natural disasters.

In FY 1999, the USDA and NASA initiated a joint program with four large grower associations; cotton, corn, wheat and soybeans. These grower associations represent over 115,000 U.S. farmers. CRSP is involved in the joint program to facilitate the requirements definitions, translate agricultural requirements to remote sensing technology performance and to provide validation of remote sensing technologies in agricultural industry applications. The intended joint program outcome is a change in agricultural practices that lead to improved efficiencies with less environmental impact from agricultural operations.

The Science Data Purchase is underway processing 83 tasking requests for over 30 sites. These events are the recognition that commercially purchased data can meet the researchers' rigorous requirements for data quality. This activity has led directly to additional mission trade studies for Ocean Winds and POAM III for the ESE Science Division. The overall effect of the program is anticipated to be reduced costs of ESE investigations.

The Workforce Development project in spatial information technology piloted in Mississippi reached fruition and was adopted in August 1999 by Secretary Richard Riley, U.S. Department of Education. This workforce development effort was a featured presentation on the 'Back to School Bus Tour' sponsored by the U.S. Department of Education. In Mississippi the pilot project has resulted in 150 interactive classroom sites through the Mississippi Educational TV Network reaching over 500,000 students.

Plans

In FY 2000, the CRSP will focus EOCAP joint commercial applications research to stimulate the development of new commercial products; e.g., oil spill containment software by EarthSat). These products will ultimately provide the basis for commercial services to continue to support the ongoing geo-spatial needs of the Agricultural and Transportation agencies and the respective markets they represent. Additional commercial sources of science data (from data buy) for global change research and applications will also be investigated for use. The science data will be made available to Earth science researchers for their investigations. These new potential commercial information products will be subject to the necessary verification and validation activities so as to increase customer confidence and product understanding. These products will provide a validated baseline of the new commercial remote sensing satellite and airborne offerings that will be available in the near future.

In FY 2001, efforts will continue to promote the development of new commercial sources of data for science research and applied commercial uses will continue to be pursued. ESE's CRSP and the U.S. Department of Agriculture will jointly conduct at least 30 joint applications research endeavors to increase efficiencies in crop development and crop yield. Working with major associations such as the National Association of Counties, National States Geographic Information Council, National Conference of State Legislators and the National Governors Association a requirements analysis of spatial data needs will be conducted. NASA science and technology have advanced to a state where they can be applied to the operational monitoring of Earth's natural resources. These organizations represent state and local governments where decisions that govern the use and care of Earth resources are

made. This initial effort will be to gather geospatial requirements and validate the requirements. The results will lead to a translation to technology performance and validation of state and local government application for geospatial technologies. Also, CRSP will endeavor to increase cost share leveraging with the industry sector, academia and other government agencies within the EOCAP and ARC programs. The ultimate goal is to effectively stimulate the development of potential commercial data products that will become self-supporting in an emerging commercial remote sensing industry.

EDUCATION

Accomplishments

ESE awarded 50 new graduate fellowships and 17 early career research grants during FY 1999. The fellowships and grants train the next generation of earth scientists and engineers, contributing to a workforce of interdisciplinary scientists to address the study of Earth as a system. These scientists and engineers will use remote sensing knowledge and data in practical fields related to Earth and environmental sciences, and the effects of natural and human-induced changes on the global environment.

In FY 1999, NASA conducted over 300 workshops to train educators in the use of ESE education products. The teachers use Earth system science concepts and applications in lesson plans and classroom activities to educate students about the effects of earth science on the environment. State education systems infuse Earth system science approaches and program content into state curriculum infrastructure. Educators use mission science and applications data to design new Earth system science-related courses to train the next generation of scientists, engineers and educators. These efforts broaden the understanding and sensitivity of students to the processes of the Earth that surrounds them, which they can effect, and are effected by, on a daily basis.

The number of schools participating in GLOBE increase to 7,767, 29% increased from the 5,900 schools participating in 1998, and 84 countries participated, a 20% increase from the 70 countries participating in FY 1998.

Plans

In FY 2000, ESE plans to award at least 50 new graduate student research grants and 20 early career fellowships in Earth science systems. We will continue funding the original EOS interdisciplinary teams through FY 2000 and those selected with the NRAs in FY 1996 through FY 1999. Beginning in FY 2000 we will conduct a NRA for a new group of EOS Interdisciplinary scientists to fit with the new way of doing EOS missions. In FY 2001, we will continue the existing 90 graduate research grants, and award at least 50 new graduate student research grants. During FY 2001, the 17 early career grants will be continued.

During FY 2000, NASA will sponsor at least 350 workshops to train teachers in the use of Earth Science education products. In FY 2001, ESE will sponsor at least 400 Earth science workshops to train educators in the use of ESE education products.

The goals of the GLOBE program will be to increase the number of schools participating in GLOBE to 10,300, a 30% increase over FY 1999, increase the number of participating teachers to 12,000, and increase the number of participating countries in GLOBE from 84, in FY 1999, to 85 in FY 2000. In FY 2001, the volume of teachers participating in the GLOBE program is expected to increase to 13,800 and to increase the number of participating countries to 87.

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

TECHNOLOGY INFUSION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Technology Infusion	[89,000]	[74,515]	89,100
New Millennium Program	[56,100]	[37,100]	50,100
Advanced Information Systems Technology	[6,500]	[12,515]	14,000
Advanced Technology Initiatives	[5,500]	[9,900]	10,000
Instrument Incubator Program	[20,900]	[15,000]	15,000
High Performance Computing and Communications	[14,500]	[21,900]	21,800
Total	[103,500]	[96,415]	110,900

Note: Technology Infusion has been moved from EOS and joined with the effort for HPCC to better account for all technology effort.

PROGRAM GOALS

The Earth Science Technology program develops and demonstrates technologies that will enable future missions, that will reduce the cost of future missions, and that will enable a maximum 3-year acquisition timeline for flight and ground systems. The program consists of five major areas that will lead to the successful and timely development and infusion of technologies into future programs. The New Millennium Program (NMP) validates space platform and instrument technologies required for future missions. NMP space-validated technologies are required before new technologies can be flown on science or operational missions. Advanced Technology Initiatives (ATI) focus and refine ESE technology requirements and advance key component and subsystem technologies required for the next generation of process and monitoring missions. The Instrument Incubator Program (IIP) develops new instruments and measurement techniques at the system level. Such new instruments and measurement techniques will be ready for inclusion in to the ESE 3-year acquisition timeline. Advanced Information Systems (AIS) develops advanced end-to-end mission information system technologies to capitalize on the technological advances of future missions and the increased data of future missions. The goals of the NASA High Performance Computing and Communications (HPCC) project are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the U. S. aeronautics, Earth science, and space science communities and to accelerate the implementation of a national information infrastructure. The ESE HPCC investment will focus on advanced developments of particular interest in Earth and space science.

STRATEGY FOR ACHIEVING GOALS

New Millennium Program

The NMP reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs through focused technology demonstrations for Earth orbiting missions. The Office of Earth Science has joined the Office of Space Science in the NMP in order to capitalize on common work from core technology development projects and specific spacecraft and instrument studies. The program will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of missions for the next century, (i.e., spacecraft, instruments and operations). The project objectives are to spawn "leap ahead" technology by applying the best capabilities available from several sources within the government, private industries and universities. These low-cost, tightly controlled developments, the Earth Observers (EOs), will take more risk in order to demonstrate the needed technology breakthroughs and thus reduce the risk of using that technology in future science missions. Missions will be selected based on their ability to meet the science needs of the future by innovative technology that would also decrease the cost and improve the overall performance of space flight missions.

Advanced Information Systems

ESE has initiated the AIS Technology Program. This new program focuses on developing new information systems concepts and capabilities that will enable us to organize, integrate, and capitalize on the increasing data now becoming available.

Advanced Technology Initiative

Increased technology work in the ATI program will be pursued in the areas of sensor and detector systems. Emphasis is being placed on developing new capabilities for Earth science sensors and integrated, autonomous, self-calibrating instruments.

Instrument Incubator Program

The IIP is expected to reduce the cost and development time of future scientific instruments for Earth science. The instrument incubator project will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The project will take detectors and other instrument components coming from NASA's fundamental technology development projects and other sources, and focus on combining them into new instrument systems which are smaller, less costly, less resource intensive, and which can be developed into flight models more quickly for future Earth science missions. This includes the key follow-on instruments for the EOS.

High Performance Computing and Communications

The NASA HPCC program consists of five discipline-related integrated projects. These projects are Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth Science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science; National Research and Education Network (NREN), managed by the Office of Aero-Space Technology, and Learning Technologies (LT).
The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The ESS project, led by GSFC, will work in close partnership with industry, academia and government. The project used the NASA research announcement process to select ten principal investigator teams and twenty-one NASA/NSF sponsored Grand Challenge investigations and to implement them on advanced parallel computers. The LT project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure and to communicate and distribute science and engineering materials to the education community. The LT project uses remote internet technologies developed by NASA and other federally funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science and engineering data.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

Earth Observer-1
Plan: February 1997
Actual: February 1997

Earth Observer-2 Plan: June 1998 Actual: October 1998	Revised schedule due to delays in initiating the selection process

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

Earth Observer-1 Plan: April 1997 Actual: June 1997	Schedule changed to accommodate a grating spectrometer, which was added to the mission

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms to their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Earth Observer-1 Plan: May 1999 Revised: June 1999	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability following failure to provide wedge filter detectors
Earth Observer-2 Plan: August 2000	After critical design review, it was determined that the SPARCLE system cost had grown significantly. After detailed peer reviews of the technical, cost and schedule status, the project was terminated. However, the progress made on the lidar technology development is still valuable and is being documented

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Earth Observer-1 Plan: December 1999 Revised: April 2000	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability and to complete system integration and tests. Currently planned to be launched in April 2000.
Earth Observer-2 Plan: not applicable	Project was terminated due to cost growth.

ACCOMPLISHMENTS AND PROPOSED RESULTS

The Earth Observer (EO-1) Advanced Land Imager (ALI) is the first mission selected under the NMP series and is scheduled for launch in spring, 2000. The EO-1 consists of an ALI instrument, a hyperspectral instrument (called Hyperion), a spacecraft, and numerous advanced technologies as an integral part of the mission. The EO-1 is in Phase C/D and has completed CDR.

Due to the manufacturing difficulties at the ALI detector contractor, the imaging capability of the ALI was rescoped to a grating imaging capability with limited swath coverage to preserve the overall mission schedule and cost. The decision was made in the summer of 1998 to continue the hyperspectral capability, however, through another contractor's design. An additional module called Hyperion to be completed by TRW will provide the hyperspectral functionality. The Hyperion delta CDR was completed this year. In spring, 2000 the EO-1 mission will be launched.

Following selection, development of the Space-Readiness Coherent Lidar Experiment (Sparcle) was started in May 1998 as EO-2. The mission was scheduled to fly an infrared laser in the cargo bay of the Space Shuttle to determine if a space-based sensor can accurately measure global winds within Earth's atmosphere from just above the surface to a height of about 10 miles. The measurement in this region of the atmosphere may lead to improved weather forecasting and a better understanding of climate-related events such as El Niño. The project was terminated due to cost growth. However, the progress in the lidar technology development is still useful for future lidar remote systems.

The Announcement of Opportunity for the EO-3 mission was released in 1999; 4 innovative measurement concepts were selected for concept definition study in February 1999. These concepts would test breakthrough technologies for remote sensing from geostationary Earth orbits. The concept definition studies were completed in September 1999. After detailed review, a Geostationary Imaging Fourier Transform Spectrometer was selected as the EO-3 mission. The concept will test advanced technologies such as large area focal-plane array, new data readout and signal processing electronics, and passive thermal switching, which will be used for measuring temperature, water vapor, wind and chemical composition with high resolution in space and time.

The ATI activities are focusing and refining ESE technology requirements, including system trade studies and the development of technology roadmaps. Architectural concepts developed under the advanced concepts element are carried forward to determine the specific system, subsystem and component performance metrics required for their implementation. A NASA Research Announcement (NRA) for instrument-related technologies was released in 1999 and proposals are currently in the evaluation phase. Awards are expected in the first quarter of 2000.

This element also advances key component and subsystem technologies required for the next generation of process and monitoring missions. An example is the current sensors and detectors project that includes the development of Light-Detection and Ranging (LIDAR) technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing. These activities are complementary to the Space Science Enterprise-supported Cross-Enterprise Technology Development Program (CETDP), NASA's primary advanced technology program developing component and subsystem technologies at early stages of maturity. While CETDP has the charter for generic technologies with value to multiple NASA enterprises, ESE's advanced technology initiatives element is focused on technologies specific to ESE needs.

For 1999 the ATI element includes the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing.

Also under this element, systems trade studies were completed in 1999 in the following areas:

- Visible/Near-IR Remote Sensing Options
- High Data-Rate Instrument Requirements
- Systems Issues on Formation and Constellation Flying
- LIDAR Studies
- Molniya Earth Orbit (MEO) Applications-Science/Cost Benefits
- Geostationary Orbit (GEO) Missions
- Advanced Microwave Radiometry
- Global Positioning System (GPS) Surface Reflection Technology for Space
- Tropospheric Measurement Options

The last quarter of 1999 saw the initiation of the Earth Science AIS Technology Program. An NRA was released with five areas of interest emphasized: 1) On-board Satellite Data Processing and Intelligent Sensor Control; 2) On-board Satellite Data Organization, Analysis, and Storage; 3) Data Transmission and Network Configuration; 4) Intelligent Platform Control; and 5) Information Systems Architectures and Standards. Awards are expected in early 2000.

The IIP supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NRAs are used as the vehicle to search the combined public and private science/technology community for the best new ideas and development capability. NASA received 123 proposals of which 27 have been selected and are under contract. Selected projects include three from industry, six from NASA field centers, eight from universities and ten from national laboratories.

The advanced geostationary study effort has been evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advance geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities have been closely coordinated between NASA and NOAA.

In FY 2000 and 2001 the technology program will continue to achieve success in timely development and infusion technologies, thereby enabling future missions and reducing their total cost. Indicators of this performance will be to; annually advance at least 25% of funded instrument technology developments one Technology Readiness Level (TRL); develop advanced information systems technologies, concepts for processing, archival, access, and visualization of ESE data; develop at least 3 technologies to demonstrate in space with the third Earth Observer New Millennium satellite; transfer at least one technology development to a commercial entity or infuse into a flight mission for operational use. These performance indicators will be refined as the Enterprise gains experience with its technology development initiatives.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

CONSTRUCTION OF FACILITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Construction of Facilities	1,500	1,000

For additional detail, refer to the Mission Support, Construction of Facility section.

BASIS OF FY 2000 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY

PROPOSED NEW STRUCTURE

CONSTRUCTION OF FACILITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Construction of Facilities	[1,500]	[1,000]	--

For additional detail, refer to the Mission Support, Construction of Facility section.

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

OLD STRUCTURE

OPERATIONS, DATA RETRIEVAL AND STORAGE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Mission operations	55,500	47,600
(Upper Atmosphere Research Satellite)	8,200	6,700
(Total Ozone Mapping Spectrometer)	2,700	3,200
(Ocean Topography Experiment (TOPEX)	11,000	9,700
(Tropical Rainfall Measuring Mission)	10,900	11,000
(Satellite Laser Ranging)	5,900	--
(Earth Science)	16,800	17,000
HPCC	14,500	21,900
INFO SYSTEMS	6,100	7,600
Total	76,100	77,100

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

PROPOSED NEW STRUCTURE

MISSION OPERATIONS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Mission operations			
(Upper Atmosphere Research Satellite)	[8,200]	[6,700]	6,700
(Total Ozone Mapping Spectrometer)	[2,700]	[3,200]	4,400
(Ocean Topography Experiment (TOPEX)	[11,000]	[9,700]	6,000
(Tropical Rainfall Measuring Mission)	[10,900]	[11,000]	9,700
(Satellite Laser Ranging)	[5,900]	--	--
(Earth Science)	[16,800]	[17,000]	15,900
Total	[55,500]	[47,600]	42,700

Note: In the proposed new structure, HPCC is located under Applications, Commercialization and Education, and Information Systems is under Earth Science Program Science

PROGRAM GOALS

Operations, Data Retrieval and Storage (ODRS) provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment.

STRATEGY FOR ACHIEVING GOALS

This project supports the observations and data management portion of Earth science activities. The project will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this project have or will migrate to the EOSDIS.

Mission Operations

The objectives of the mission operations program are to acquire, process, and archive long-term data sets and validated data products. These data sets support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft such as UARS, TOPEX, ERBS, TOMS, TRMM, and processing of acquired data. Key users of UARS data include NOAA, the Naval Research Laboratory, GSFC, JPL, Canada, the United Kingdom, and a number of universities including the University of Michigan, the Georgia Institute of Technology, the University of Washington, the State University of New York, and the University of Colorado. Key TOMS proponents include NOAA, Russia (manifested a TOMS on their Meteor 3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users are a diverse set of institutions including NOAA (manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

Key participants involved in the Alaska Synthetic Aperture RADAR (SAR) Facility include the European Space Agency Remote Sensing Satellite (ERS)-1 and -2), Japan Earth Remote Sensing Satellite (JERS)-1), Canada (RADARSAT), GSFC, JPL, and the University of Alaska which hosts the ASF. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations on almost every continent and include: Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

The Satellite Laser Ranging (SLR) System is NASA's contribution to a worldwide laser ranging network. In additional to providing extremely precise tracking for a number of spacecraft (including TOPEX and a host of international missions), the SLR network makes significant contributions to Earth science (such as precise measurements of the gravity field and the station's vertical position with respect to the Earth's center of mass).

The Optical Transient Detector (OTD) instrument has numerous customers for data including NASA, NOAA, USAF, Massachusetts Institute of Technology, Texas A&M, University of California at Los Angeles, Colorado State, and international requests for data from Chile; German Aerospace Center (DLR); University of Frankfurt, Germany; the Swiss Institute of Atmospheric Physics; South Africa; Mexico; Hungary; Tel Aviv University and Haifa University, Israel; the United Kingdom Meteorological Office; France; Potsdam Institute for Climate Impact Research, Germany; and China.

SCHEDULE AND OUTPUTS

OPERATIONAL SPACECRAFT/INSTRUMENTS

Common to all missions: Archive 95% of planned data acquisition	The primary criteria for success of an operational spacecraft are to obtain 95% of the planned data acquisition.
UARS (launched September 1991) continuing operations	The spacecraft launched in September 1991 with an expected five-year mission life. It has gone well beyond the expected mission life providing data to support improvements monitoring the processes that control upper atmospheric structure and variability, the response of the upper atmosphere to natural and human-induced changes, and the role of the upper atmosphere in climate variability. The spacecraft is transitioning to real-time operations due to a second recorder failure in November 1999. 95% operational. Processing 4,000 Bytes/second.
TOPEX/Poseidon (launched August 1992) continuing operations	The spacecraft launched in August 1992 with an expected three-year mission life. The extended mission was defined to be three additional years. It is now in the final year of this extended mission life. 100% operational. Processing 2000 Bytes/second.
ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations	The ERBS spacecraft launched in October 1984. It has gone well beyond the expected mission life. 67% operational. SAGE processing 1,600 Bytes/second. ERBE processing 200 Bytes/second.
Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RADARSAT (launched 1995) ADEOS (launched 1996)	The Alaska SAR Facility is a ground receiving station and data processing station with no "end of life" defined. It supports ERS-1, JERS-1, ERS-2, and RADARSAT. All of these are international missions. There are currently no unique metrics defined for ASF other than the common metric listed above. 67% operational. Processing 575 Bytes/second.

OTD (launched 1995) continuing operations	This instrument was launched in 1995 as a six-month technology demonstration. It has far exceeded its designed mission life.
TOMS FM-3 (launched July 1996) continuing operations	The TOMS-EP spacecraft was launched in July 1996 with an expected five-year mission life. It is currently in its primary mission phase. The first global ozone image was produced and released September 13, 1996. Automated processing and distribution of science products began September 20, 1996 and Internet distribution started on October 7, 1996. 100% operational. Processing 250 Bytes/second.
TRMM (Launched November 1997) continuing operations	The spacecraft launched in November 1997 with a three-year mission life. All operations are nominal, except the CERES instrument is non-operational due to an anomaly with Data Acquisition Assembly Converter. 100% operational. Processing 250,000 Bytes/second.
SeaStar / SeaWifs / Ocean Color (Launched August 1997 continuing operations for data processing)	The spacecraft launched in August 1997. This is a data buy from Orbital and the operation of the spacecraft is an Orbital responsibility. 100% operational. Processing 41,700 Bytes/second.
Landsat-7 **Launched April 1999**	Landsat-7 was launched April 15, 1999 and declared operational in July 1999. After NOAA withdrew from the program in late 1998, the USGS agreed to operate the satellite through FY 2000. 100% operational. Processing 250 scenes/day.

ACCOMPLISHMENTS AND PROPOSED RESULTS

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decisions on such matters as the impact of deforestation, ozone depletion, and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years. These added demands are being addressed in the agency's initiative to consolidate supercomputer-based information systems.

In the mission operations project, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products.

User requirements will be met in 2000 and 2001 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; and continuing receipt of ERS-1, JERS-1, and RADARSAT data at the Alaska SAR Facility, in addition to , OTD, SeaStar/SeaWifs, TOMS and TRMM.

BASIS OF FY 2001 FUNDING REQUIREMENT

PROPOSED NEW STRUCTURE

INVESTMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Minority University Research & Education Program (MUREP)	[7,300]*	[7,300]*	8,800
Education	--	--	1,500
Total	[7,300]*	[7,300]*	10,300

* FY 1999 and FY 2000 MUREP covered in Applications, Commercialization and Education (ACE).

PROGRAM GOALS

The above funding requirements represent the ESE budget contribution to the Minority University Research and Education Programs (MUREP) and the Education Program.

STRATEGY FOR ACHIEVING GOALS

The Earth Science Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Earth Science Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Earth Science Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Earth Science mission holds for students and educators. The unique character of Earth Science exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with Earth Science Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of Earth Science activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Global Observations to Benefit the Environment	5,000	5,000

For additional detail, refer to the Applications, Commercialization, and Education section.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

LAUNCH SERVICES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Launch Services	4,200	

For additional detail, refer to EOS, Terra section.

BASIS OF FY 2000 FUNDING REQUIREMENT

OLD STRUCTURE

SHUTTLE RADAR TOPOGRAPHY MISSION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED
	(Thousands of Dollars)	
Shuttle Radar Topography Mission		6,200

For additional detail, refer to the Earth Probes section.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

AERO-SPACE TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Aero-space research and technology	1,198,548	984,849	1,058,000	SAT 4.1-1
Commercial Programs	140,352	140,005	135,000	SAT 4.2-2
Total	1,338,900	1,124,854	1,193,000	

AERO-SPACE RESEARCH AND TECHNOLOGY PROGRAMS

PROGRAM GOALS

NASA is responsible for addressing aeronautics and space priorities as outlined by the National Science and Technology Council in national aeronautics and space policies. The responsibility of industry and operational government agencies is to meet their near-term customer requirements through evolutionary advancements to their products. The Aero-Space Technology Enterprise's responsibility is to provide revolutionary advancements in science and technology that sustain global U.S. leadership in civil aeronautics and space. To meet this challenge, the Enterprise's objectives are grouped into three synergistic goal areas or "pillars": Global Civil Aviation, Revolutionary Technology Leaps and Access to Space. The objectives within these goals are framed in terms of final outcomes once NASA-developed technology is integrated with, and further developed by, its partners. The technologies associated with these goals and objectives are pre-competitive, long-term, high-risk research endeavors with high-payoff in terms of market growth, safety, low acquisition cost, consumer affordability and cleaner environment. The goals and objectives are ambitions and stretch the boundaries of our current knowledge and capabilities. Priorities are established and resources aligned to enable achievement of the high priority objectives on a timely basis.

Pillar One: Global Civil Aviation

Global civil aviation provides the backbone for global transportation, the very basis of global economic and cultural exchange and integration. It is a large and growing market that the U.S. has traditionally led. Projected growth approaches a tripling of air traffic over the next twenty years. Moreover, examination of various alternative futures suggests that there is also the potential for greater dispersion of operations, very high value for flexible, ultra-reliable operations, and increasing utilization of aircraft with unique operational characteristics.

A need exists to address the fundamental, systemic issues for the aviation system to ensure the continued growth and development appropriate to the needs of the national and global economies. These systemic issues—safety, capacity, environmental compatibility, and affordability cut across markets including large subsonic civil transports, air cargo, commuter and general aviation, and rotorcraft. To ensure these systemic issues do not become constraints, dramatic improvements should be aggressively pursued. Therefore, the Enterprise has worked with its partners to identify five enabling technology objectives to sustain the United States aeronautics leadership by providing high-risk technology that cuts across all markets in Global Civil Aviation:

- Reduce the aircraft accident rate by a factor of five by 2007 and by a factor of 10 by 2022.
- Reduce emissions of future aircraft by a factor of three by 2007, and by a factor of five by 2022.
- Reduce the perceived noise levels of future aircraft by a factor of two (10db) from today's subsonic aircraft by 2007, and by a factor of four (20bd) by 2022.
- While maintaining safety, double the aviation system throughput, in all weather conditions, by 2007.
- Reduce the cost of air travel by 25 percent by 2007 and by 50 percent by 2022.

Pillar Two: Revolutionary Technology Leaps

In addition to the systemic issues associated with the global civil aviation system, there is tremendous opportunity to explore high-risk technology to revitalize existing markets and open new markets. Examination of future trends and various alternatives highlighted the opportunities in high-speed civil transportation, general aviation and experimental aircraft. In addition to new market opportunities, there exist opportunities to revolutionize the way aircraft and space transportation systems are designed and developed. It is also critical to recognize that achieving the goals in all three pillars requires the rapid exploration and validation of concepts and technologies in the flight environment.

The Enterprise and its partners have identified three high-risk enabling technology objectives that can revolutionize air travel and the way in which aerospace vehicles are designed, built and operated:

- Reduce the travel time to the Far East and Europe by 50 percent by 2022, and do so at today's subsonic ticket prices.
- Invigorate the general aviation industry, delivering 10,000 aircraft annually by 2007 and 20,000 aircraft annually by 2022.
- Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time in half for aircraft and space transportation vehicles by 2007 and by 75% by 2022

Pillar Three: Access to Space

NASA's primary space launch role is to develop and demonstrate pre-competitive next-generation technology that will enable the commercial launch industry to provide truly affordable and reliable access to space. NASA and the U.S. aerospace companies have embarked on an unprecedented partnership aimed at attaining revolutionary improvements in launch system cost, performance, and reliability. In response to National Space Policy and the NASA Strategic Plan, two enabling technology objectives have been identified to dramatically increase the contribution to the National goals in space:

STRATEGY FOR ACHIEVING GOALS

When the Enterprise identified the three pillars and ten enabling technology objectives, it was recognized that they are highly ambitious and will stretch the boundaries of the U.S. knowledge and capabilities. In order to achieve these National objectives, NASA carries out its aero-space technology mission in close partnership with U.S. industry, academia and other Federal agencies, such as the Department of Defense (DoD) and the Federal Aviation Administration (FAA). During FY 1998, the Enterprise developed detailed roadmaps to define the path that it would need to follow in order to allow this partnership to achieve these objectives. The Enterprise budget has been realigned to concentrate resources on the timely accomplishment of several high-priority objectives (i.e., aviation safety, emissions reduction, capacity, next generation design tools and experimental aircraft, and access to space) that directly impact the general public, have potential for true leapfrog advancements or support NASA's space mission. Progress toward other objectives continue through fundamental research.

As part of the FY 2001 budget development, the Aeronautical and Space Research and Technology Base programs have been integrated into a unified Aero-Space Research and Technology Base program and three new focused research programs have been added. As a result of these changes, the Enterprise will be able to accelerate its efforts to achieve its access to space goals and continue active programs associated with noise reduction and the invigoration of the General Aviation industry. Each of these items are discussed below.

Small Air Transport System (SATS). The objective of SATS is to develop and demonstrate technologies for small aircraft that will enable safe, efficient use of these aircraft at small, public use airports. Community vitality and economic opportunity are dependent on access to the high speed transportation afforded by small aircraft. Building on NASA's success in developing general aviation technologies, most notably the Advanced General Aviation Transport Experiments (AGATE) project, SATS addresses the technical barriers that have impeded growth in this area: safety of flight and accessibility to underutilized public use facilities. SATS will develop the vehicle and the infrastructure technologies to improve safety by reducing the accident rate of small aircraft to that of commercial

transports, utilize the nation's under-used airspace and landing facilities at non-hub airports in all weather conditions, and increase capacity for efficient operations of commuter, regional and runway independent aircraft at hub airports.

Quiet Aircraft Technology. This program will build upon the highly successful efforts resulting from the NASA/FAA Noise Reduction program. The Quiet Aircraft Technology program is a direct result of the National Science and Technology Council *National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility*, November 1999 and the NASA/FAA vision for a noise-constraint-free air transportation system that would contain the 65 decibel contour within airport boundaries, a 10 decibel reduction from 1997 state of the art. It will develop technologies for engine and airframe source noise reduction and advanced operations to reduce community impact.

2nd Generation Reusable Launch Vehicle (RLV). _Low-cost space transportation remains the key enabler of a more aggressive civil space program. A central tenant of the National Space Policy is the transition of routine space activities to the private sector to concentrate NASA resources on high-leverage science research, technology development, and exploration activities. By 2005, NASA will conduct competitive launch services procurement to support the launch requirements of both human and robotic spaceflight operations. The objective will be to dramatically improve safety while significantly reducing the cost of such launch services, thus eliminating the current need for the Government to own and operate the full system.

The President's 2001 Budget supports new funding for a 2nd Generation RLV to enable this competition. The key element of the 2nd Generation RLV is a 2nd Generation RLV program that will substantially reduce the technical, programmatic and business risks associated with developing a safe, reliable and affordable 2nd Generation RLV architecture. The program will invest in technology development, business planning, design and advanced development efforts to enable at least two competitive options for a new architecture. Identification and development of systems to meet NASA's unique space transportation needs on commercial vehicles and the near-term pursuit of alternative access for key Space Station needs are also both critical elements of this effort. The program will be implemented to assure that the full-scale development of any new systems can be initiated no later than 2005.

Commercial Technology Programs

Since its inception in 1958, NASA has been charged with ensuring that NASA-developed technology is transferred to the U.S. industrial community to improve the competitive position of the U.S. in the world community. The scope of the commercialization effort encompasses all NASA technologies created at NASA centers by civil servants, as well as innovations from NASA contractors. The technology commercialization program consists of: (1) a continuous inventory of newly developed NASA technologies; (2) an up-to-date searchable database of this inventory; (3) assessments of the commercial value of each technology; (4) dissemination of knowledge of these NASA technology opportunities to the private sector; and (5) support of an efficient system for licensing NASA technologies to private companies. In addition, NASA commercialization efforts also include the operation of the Small Business Innovation Research program, which is designed to enhance NASA's use of small business technology innovators and lead to increased commercialization of NASA technology with small firms.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY **AERO-SPACE RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Research and technology base	488,441	581,620	539,400	SAT 4.1-2
Focused programs	710,107	403,229	507,400	SAT 4.1-23
Investments	(7,000)	(7,200)	11,200	SAT 4.1-73
Total	1,198,548	984,849	1,058,000	
Distribution of Program Amount by Installation				
Johnson Space Center	5,492	2,025	5,667	
Kennedy Space Center	1,779	4,446	10,555	
Marshall Space Flight Center	317,429	191,745	236,574	
Stennis Space Center	22,774	29,658	10,760	
Ames Research Center	205,818	197,034	211,477	
Dryden Flight Research Center	86,581	98,521	99,224	
Langley Research Center	280,983	198,913	237,734	
Glenn Research Center	221,599	186,187	194,870	
Goddard Space Flight Center	4,478	1,227	3,781	
Jet Propulsion Laboratory	6,111	4,072	10,452	
Headquarters	45,504	71,021	36,906	
Total	1,198,548	984,849	1,058,000	

BASIS OF FY 2001 FUNDING REQUIREMENT

RESEARCH AND TECHNOLOGY BASE

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Information Technology	66,592	77,800	115,979
Vehicle System Technology	138,493	157,537	136,275
Propulsion & Power	75,417	76,268	75,498
Flight Research	63,585	70,715	80,950
Operations Systems	43,353	17,000	17,475
Rotorcraft	27,201	26,900	26,654
Space Transfer & Launch Technology	64,300	136,500	70,569
Minority University Research and Education Program	7,000	7,200	(11,200)
Construction of Facilities	2,500	11,700	16,000
Total	488,441	581,620	539,400

PROGRAM GOALS

The goal for NASA's Research and Technology (R&T) Base is to serve as the vital foundation of expertise and facilities that consistently meets a wide range of aeronautical and space transportation technology challenges for the nation. The R&T Base is intended to provide a high-technology, diverse-discipline environment that enables the development of new, revolutionary, aerospace concepts and methodologies for applications in industry. The R&T Base has an objective to develop revolutionary concepts, highly advanced, accurate computational tools, and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems that contributes to one or more of the Aero-Space Technology Enterprise goals and lay the foundation for future focused programs to address these goals: Global Civil Aviation, Revolutionary Technology Leaps and Low Cost Access to Space. This work constitutes a national resource of expertise and facilities to respond quickly to critical issues in safety, security, transportation, and the environment. These same technological resources contribute to the overall U.S. defense and non-defense product design and development capabilities.

STRATEGY FOR ACHIEVING GOALS

A major restructuring and replanning of the Aero-Space Enterprise's Base R&T program was accomplished during 1999 to integrate the Enterprise's existing space transportation and aeronautics Base R&T development programs into a single entity. This restructuring better aligned the required technology development efforts with core competencies and brought the expertise, resident

in the aeronautics research centers, to bear on the technological challenges associated with space transportation. Secondly the integration of the space and aeronautics development needs resulted in a synergistic technology development plan that better utilized our resources, eliminated overlaps, and allowed dual use, between the space transportation and aeronautics users, to be included as part of the planning process.

Continuous advances characterize the technology environment for success in aerospace across a wide range of disciplines, as well as developments of revolutionary technology. The R&T Base is critical to technological preeminence in the worldwide aerospace market. Through basic and applied research in partnership with industry, academia, and other government agencies, NASA develops critical high-risk technologies and advanced concepts for U. S. aircraft, spacecraft, launch vehicles, and advanced turbomachinery-based engine industries. These advanced concepts and technologies allow safe, highly productive global air and space transportation systems that include a new generations of environmentally compatible, reliable, safe, and economical U. S. aircraft, spacecraft, and launch vehicles that are competitive in the marketplace.

The R&T Base is an essential element of the Enterprise, for it is here that new technologies that lead to future advanced aerospace products are conceived. The R&T Base provides a strong foundation for the fundamental understanding of a broad range of physical phenomena, development of computational methods to analyze and predict physical phenomena, and experimental validation of key analytical capabilities. It is this capability that allows NASA to provide authoritative data to national policy makers in areas such as the environmental impact of aero-space systems. The R&T Base also develops revolutionary concepts, highly advanced, accurate computational tools and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems and high performance aircraft. A significant portion of the research and concept development in the R&T Base is performed through partnerships and cooperative agreements with the aerospace industry and other government agencies to facilitate rapid technology transfer. Also, the R&T Base supports the vast majority of the Enterprise's peer-reviewed fundamental research with academia and industry. The program also provides the capability for NASA to respond quickly and effectively to critical problems identified by other agencies, industry or the public. Examples of these challenges are found in: accident investigations, lightning and radiation effects on avionics, flight safety and security, wind shear, crew fatigue, reducing environmental impacts of aeronautical systems, structural fatigue, spacecraft/launch system anomalies, and aircraft stall/spin.

One of the key factors in aeronautical research is an extensive use of research facilities that are located at the four aeronautical research centers: 1) Ames Research Center, 2) Dryden Flight Research Center, 3) Langley Research Center, and 4) Glenn Research Center -- and the Marshall Space Flight Center (MSFC). Many facilities, such as the National Transonic Facility, the National Full-Scale Aerodynamics Complex, the Icing Research Tunnel and the fleet of research aircraft are unique in the United States and even the world. Other factors underpinning continued governmental support of aeronautical research include:

- The public-good character of much of the research (safety, environment, certification, national security),

- Large disincentives for private sector investment in long-term, high-risk aero-space R&T. Due to the long recoupment period for aero-space research and technology development, an individual company can rarely capture the full benefit of these investments.

- The extensive breadth and depth of technologies required to produce a superior aircraft or space transportation system,

- The unique cadre of experienced NASA technical personnel.

The Aero-Space Technology R&T is a framework of seven systems oriented, customer driven programs, that serve the needs of the full range of aeronautical vehicle classes. The seven R&T Base programs are:

1. Aero-Space Information Technology: The primary focus of this program is to perform leading-edge research in advanced computing systems and user environments, revolutionary software technologies and pathfinding applications in integrated design. The Intelligent Synthesis Environment (ISE) is aimed at making substantial progress toward fulfilling the NASA Administrator's vision for revolutionizing next generation science and engineering capabilities. ISE will achieve this vision by developing revolutionary ISE-related technologies; engineering practices and coordinating related on-going NASA activities, industry activities, other government agency initiatives and university research.

   The overarching goal of ISE is to develop the capability for personnel at dispersed geographic locations to work together in a virtual environment, using computer simulations to rapidly model the complete life-cycle of a product/mission before commitments are made to produce physical products. This capability includes processes, methods, tools, integration architecture and user environments which enable integrated end-to-end life-cycle design in a geographically distributed collaborative environment. ISE will bring this capability into practice on selected NASA application cases with reusable launch vehicles as the first priority application testbed. The implementation goal is to reduce design cycle time in half, with a comparable reduction in testing and costs due to rework

2. Aero-Space Vehicle Systems Technology: The program develops technologies that have application to all flight vehicles with emphasis in areas such as: conceptual design; aerodynamic and structural design and development; flight crew station design; and airborne systems design and testing.

3. Aero-Space Propulsion and Power Technology: The purpose of this program is to design and develop efficient, safe, affordable and environmentally compatible propulsion system technologies for subsonic and high speed transports, general aviation, high performance aircraft, and access to space.

4. Flight Research: The technology development under this program is aimed at remotely piloted aircraft, high performance aircraft, hypersonics, and tools and test techniques

5. Operations Systems: This program develops critical technologies in the areas of operational human factors, relevant cockpit systems, weather and hazardous environment characterization and avoidance systems, air traffic management, and communications, navigation and surveillance systems.

6. Rotorcraft: This program develops technology for improved flight safety; reduction of noise for passengers and the community; design tools for reduced design-cycle time and reduced manufacturing costs of rotorcraft.

7. Space Transfer & Launch Technology: The STLT Program is the technology-based program for unique space transportation requirements. Future revolutionary advances in space transportation technology will be developed in this program to reduce costs and increase reliability and performance across the entire mission spectrum. Advanced technologies will be developed and ground-tested to bring them to readiness levels where they can either be adopted by industry, or if necessary, flight-proven. The STLT Program will focus on technological advances with the potential to increase the safety / reliability

   In addition, STLT will make key technology investments for in-space transportation systems to reduce costs, system mass and trip time for future in-space missions. The STLT utilizes competitive technology selection and procurement processes wherever feasible in order to maximize the involvement of the myriad traditional sources of space transportation technology throughout the country, as well as to bring in potential new sources. An inter-center process has been established to prioritize STLT investments based on their system payoff in terms of improvements in mission safety, reliability, capability, cost, operability and responsiveness. The goals, objectives, and progress of the STLT will be evaluated on a yearly basis by an external, independent panel of nationally recognized experts to ensure program content is consistent with government and industry priorities, and that the program is yielding the maximum possible return on the taxpayers' investment.

   a 2nd Generation Reusable Launch Vehicle (RLV) – Development of technologies required by a 2nd generation RLV. Currently includes the Fastrac Engine and RLV Focused Projects. RLV Focused activities will be strongly driven by industry needs. These projects support the Aero-Space Technology Enterprise's Goal 9.

   b In-Space - Development of technologies for upper stages, Earth orbital and planetary transfer and interstellar precursor missions. The needs of the commercial sector, NASA Human Exploration and Development of Space and Science Enterprises guide in-Space projects. These projects support the Aero-Space Technology Enterprise's Goal 10.

   c Advanced Launch Technologies – Development of technologies which advance the state-of-the-art in propulsion, airframe and launch vehicle systems, operations and integrated vehicle health management towards the long-term Aero-Space Technology Enterprise's Goal 9 technology objectives. Technology priorities are derived from the contribution to overall transportation system goals. While focused on long-term goals, many early Spaceliner demonstrations will support 2nd Generation RLV needs.

   d Space Transportation Research – Research into very advanced, breakthrough concepts for revolutionizing space travel.

Accomplishments over the past year continue to provide a foundation for longer-term technology development, address national needs as outlined in the Enterprise's Three Pillars for Success, and provide research facilities operations and expert consultation for

industry during their product development design and build processes. Conceptual studies took into consideration various state-of-the-art technologies to reduce aircraft and space transportation systems design, manufacturing, and operational costs. The conceptual studies addressed breakthrough technology requirements for future commercial and general aviation transports, rotorcraft, space access, missions to the planets and beyond, hypersonic vehicles, as well as high performance and high altitude remotely piloted aircraft. The R&T Base continues to sponsor and conduct research using cooperative programs, not only to leverage resources for technology development, but also to ensure timely technology transfers to U. S. customers.

SCHEDULE AND OUTPUTS

Information Technology

Adaptive coefficient based controller flight demonstrated in shadow mode on the F-15 ACTIVE aircraft. Plan: March 1999 Actual: March 1999	Achieve neural net reconfiguration in flight. An adaptive neural-net based intelligent flight controller was successfully demonstrated on the F-15 ACTIVE aircraft during flight tests.
Demonstrate prototype heterogeneous distributed computing environment Plan: September 2000	Demonstrate tools and software to link distributed computing test-beds at multiple NASA Centers into a single "virtual" supercomputing environment.
Demonstrate ability to adapt to loss of control surfaces and maintain control of aircraft Plan: March 2001	Combine Propulsion Controlled Aircraft (PCA) control laws with the Intelligent Flight Control System (IFCS) to demonstrate a new capability for adapting to absence or loss of any and all control surfaces resulting from failures or malfunctions.
Demonstrate prototype data communications scheme for NAS Plan: September 2001	Demonstrate a prototype data communications scheme for the National Airspace System.

Intelligent Synthesis Environment

CEE Prototypes Plan: 2nd Qtr, 2001	Establish prototype collaborative engineering environments

Methods and Tools Architecture Plan: 4th Qtr, 2001	Establish architecture for seamless interoperability of next generation methods and tools

Aero-Space Vehicle System Technology

Physics-based prediction of airframe noise components Plan: March 2000	Develop physics-based computation of airframe noise components including flap-side edge, slat, and landing gear.
Non-linear composite pressure structure Plan: September 2000	Fabricate and test non-circular composite pressurized structural sub-component and compare with analytical predictions.
Hyper-X Mach 7 Flight 2 Plan: December 2000	Envelope expansion of Airframe Integrated, Dual-Mode Scramjet powered vehicle in flight at Mach 7.
Complete Blended Wing Body (BWB) test vehicle Plan: March 2000	Complete and integrated blended-wing-body low-speed flight research vehicle prepared and delivered to Dryden Flight Research Center for final validation and testing. (December 2000)
Systems Analysis of Short Takeoff and Landing (STOL) & Extremely Slow Take Off and Landing (ESTOL) Plan: June 2001	Complete Systems Analysis of STOL & ESTOL studies.
Demonstration of "smart" panel technology Plan: September 2001	Smart Wing Phase II complete – wind tunnel test of a smart Uninhabited Combat Air Vehicle (UCAV) with hingeless control surfaces.
Mach 10 Research Vehicle Flight. Plan: September 2001	Demonstrate an airframe integrated, dual-mode scramjet powered vehicle in flight at Mach 10.

Propulsion Systems

Demonstrate 900°F SiC sensor on an engine. Plan: September 2000	Commercial grade, high temperature sensor demonstrated at 900°F.

Demonstrate 'smart' turbomachinery concepts to minimize pollutants throughout mission cycle. Plan: September 2000	Active combustion control strategy rig demonstrated, 20dB suppression of instability driven acoustic energy.
Complete Inlet Test for Pulse Detonation Engine Flight Research Project Plan: May 2001	Demonstrated unsteady inlet flow performance for PDE ground and flight research tests.
Demonstrate viability of hot section foil bearing Plan: September 2001	Complete Core Hot Section Radial Foil Bearing Rig Testing
Crack resistant blades Plan: September 2001	Provide alloys for blades that are more crack-resistant.

Flight Research

Complete low-altitude flight of Helios Plan: March 2000 Actual: December 1999	Demonstrate a solar-powered remotely piloted aircraft with wingspan greater than 245 feet suitable for flight to 100,000 feet in altitude or a duration of 100 hours once outfitted with high performance solar cells.
Demonstrate continuous "over the Horizon" control of RPA Plan: June 2000	Flight demonstration of reliable "over the Horizon" control of RPA utilizing low cost commercial satellite systems.
Complete development of laboratory (heavy weight) energy storage Plan: September 2001	Demonstration of fuel cells with 300 milliamps per square centimeter at a cell voltage of .8 volts and an electrolyzer with 500 milliamps per square centimeter at a cell voltage of 1.6 volts.
Demonstrate solar power RPA flight to 100,000 feet Plan: September 2001	Helios RPA achieves 100,000 foot altitude under solar power.

Aviation Operations Systems

Define effects of in-flight activity breaks on alertness Plan: July 2000 Revised: June 2000	Conduct a full-mission simulation experiment that utilizes in-flight activity breaks as the controlled variable; produce report documenting their efficacy.
Identify and evaluate existing crew strategies for reducing errors in the management concurrent tasks. Plan: May 2001	Determine how the demands of managing multiple concurrent tasks contribute to crew errors in aviation, document in report.
Downselect of ground-based remote sensor technologies for a prototype ground-based System to sense icing conditions. Plan: June 2001	Review, evaluate and select candidate remote sensing technologies, document in a NASA TM.

Rotorcraft

Flight demonstrate active control technology for rotorcraft interior noise reduction; provide interior noise prediction methods for a range of rotorcraft types. Plan: June 2000	Demonstrate cabin noise reductions resulting from improved interior panel isolator mount designs and from an active structural acoustic control system concept; validate improved interior noise analytical prediction tools covering a wide frequency range and alternative designs.
Develop and validate capability for large-scale rotor testing. Plan: September 2000	Wind tunnel demonstration of capability to test large-scale rotor systems (up to 50,000 lb. thrust and 6000 HP) using newly developed Large Rotor Test Apparatus.
Rotorcraft Crashworthiness. Plan: January 2001	Demonstration of strong correlation of analytic model predictions with full-scale water/soft-soil-impact test results; demonstration of analytic model for designing energy-attenuating rotorcraft structures for crashes onto water, soft soil and rigid surfaces.

Health and Usage Monitoring Systems (HUMS) Certification Protocol. Plan: February 2001	Detailed protocols for a sanctioned demonstration leading to rotorcraft component-life-credit certification -- accepted by both the FAA and the DoD. RITA diagnostic algorithms will be evaluated and a set of usage requirements will be generated. Preliminary design for HUMS implementation on various aircraft will be written. Plans for a limited flight evaluation of Cockpit Situational Awareness Algorithms will be developed.
Ultra-safe gear design guide. Plan: March 2001	Complete 2-D gear crack analyses and experiments. Document analysis and test results in a comprehensive report and technical conference paper.
Flight validate advanced control laws/modes for reduced pilot workload and increased safety in low visibility Plan: March 2000 Revised: September 2001	Achieve Level 1 pilot ratings in Rotorcraft Systems Concept Airborne Laboratory (RASCAL) UH-60 for flying tasks typical of civilian operations. Milestone rescoped and reworded to conduct flight validation based on baseline RASCAL control laws due to funding shortfalls.

Space Transfer & Launch Technology

LOX Densifier verification testing and completion of hydrogen densifier build Plan: September 2000 Revised: June 2000	"Complete RLV focused technologies tasks" milestone divided into five separate milestones (Hydrogen densifier, MMC & PMC, thrust cell chambers), advanced TPS panel, composite cryo tank, and composite LOx tank) to provide clarity and reflect different schedules. Validate design, technology and operational characteristics of X-33 scale liquid oxygen propellant densifier, and prove readiness for use in experimental propulsion ground test or flight test program. Completion of Hydrogen densifier assembly.
Complete fabrication of Metal Matrix Composite (MMC) & Polymer Matrix Composite (PMC) thrust cell chamber demonstration units Plan: August 2000	Delivery of 5 different demonstration units, each fabricated with different composite structural jackets surrounding a new copper alloy liner. Will demonstrate successful fabrication of thrust cell chambers using new material systems that offer weight savings up to 40%.
NSTAR Engine ground demonstration Plan: January 2000 Revised: September 2000	Complete NSTAR Mission Profile (100% design life) ground testing for Deep Space-1 (concurrent, identical firing of an NSTAR engine in a vacuum chamber with the actual firing sequence of the in-flight propulsion system).

Complete Small Payload focused technologies and select concepts Plan: September 2000 Actual: Deleted	Concepts will be selected for flight demonstration of a reusable first stage based on FY 1999 and FY 2000 technology development. Deleted as result of decision to terminate the Bantam project.
Advanced TPS panel development, fabrication and test Plan: September 2000	Database of metallic TPS coatings and materials. Advanced TPS concept validated through ground test. Metallic TPS is more robust and required significantly less maintenance than current ceramic tile and blanket TPS. Metallic TPS can also offer reduced weight, improved vehicle performance through higher temperature metallic materials and all-weather operation
Composite Cryogenic Tank and Integrated Structures Demonstration Plan: July 2001	Validation of PMC cryogenic LH2 and LOX tanks to include validation of compatible materials systems and processes, fabrication and joining of large-scale articles, and demonstrated thermal-structural performance. Significant weight reduction for RLV cryotanks and primary structure can be quantified through actual test data.
Complete preliminary design of LOX tank for X-34 Plan: March 2000	Hold preliminary design review of composite LOX tank for X-34. The tank being fabricated in this activity will become the first composite liquid oxygen tank to be flight tested. The long-term impact of utilizing low-cost lightweight composites in liquid oxygen tank applications will be to reduce the cost of access to space.
Combined Cycle Engine System Selection for first Flight Demonstrator Plan: September 2001	Engine preliminary design reviews complete. Establish preferred airbreathing engine concept for FY 05 flight demonstrator that will directly support the long term objectives of Goal 9.
Combined Cycle Flowpath Definition and Testing Completed for First Flight Demonstrator Plan: September 2001	Flowpath characterizations complete. Used as criteria for combined cycle demonstrator engine selection that directly supports the long term objectives of Goal 9.

ACCOMPLISHMENTS AND PLANS

Information Technology

In FY 1999, the Information Technology program further developed integrated design techniques, including wind tunnel flow quality and testing productivity enhancements, more accurate model positioning and balance calibration systems, on-line real-time test data and more versatile user interfaces. Of particular focus within the integrated design effort was the transition of the technology

from aircraft to space transportation systems applications. Specifically, the integrated design tools was adapted and applied to thermal protection system design of reusable launch vehicles. Together with advanced instruments and data acquisition systems, this effort continued the development of capabilities for real-time design exploration of aerospace vehicles. An intelligent, neural-network flight control system was flown on an F-15 research aircraft, and work initiated to integrate this capability with propulsion control, health monitoring and diagnosis capabilities. Intelligent tools for an aviation safety data sharing network was developed and a prototype data-sharing network will be established. An effort to demonstrate real-time data sharing with a flight vehicle is planned. Next-generation computing systems was developed that take advantage of geographically distributed resources, requiring new capabilities in network quality of service, data storage, retrieval and analysis, and system operations including scheduling, planning, and accounting. Software technology developments contributed to enhancing the reliability of complex, flight-critical systems (such as flight control systems), and reducing the cost of producing, verifying, and validating these systems. Tools for ensuring and verifying the integrity of wireless data communications to enhance the safety of the future National Airspace System were developed and demonstrated.

In FY 2000, the Information Technology program will complete a demonstration of real-time aerospace design exploration. The developed environment will include remote connectivity, access to experimental data in real-time, capability to perform simulations in near-real-time, and access to databases with analysis tools to support design. All of these capabilities will be coupled with newly developed instrumentation and data systems to provide previously unavailable experimental data. In addition to reductions in access time to high-fidelity simulations data, specific goals of the system include a reduction in access time to experimental data by a factor of five, and a reduction in access time to archived database sources by a factor of two. Improvements in software technology will result in the development of verifiably correct program synthesis technology. Tools will be demonstrated to reduce time in software coding and testing. Specifically targeted applications will demonstrate these tools on real-world, complex software development activities meeting NASA mission requirements. Finally, the first prototype of a geographically-distributed heterogeneous high-end computing system will be developed and demonstrated for NASA supercomputing requirements. The developed software tools will link multiple NASA supercomputing assets seamlessly and transparently to the end-users. The overall computing capability enabled by this technology will allow for geographically dispersed engineering collaboration and greater peak computing power.

In FY 2001, the Information Technology Base Program will demonstrate an environment for aerospace hardware design that will provide real-time access to flight simulation data during a flight simulation test, with computational simulation data available as input to the flight simulation. This research will provide a capability for assessment of design impacts on aerospace vehicle controls and handling qualities earlier in the design cycle, leading to reduce design costs and improve designs. A cross-fidelity aerospace design system being developed in the IT program will enable the use of high-fidelity Computational Fluid Dynamics design codes in a design paradigm focused on rapid turnaround of computational solutions. Software technology being developed by the IT program will result in increases in safety and productivity for the National Airspace System. Automated program synthesis technology will provide a next-generation technique for reducing software development cycle time and cost. High-confidence assembly of programs via automated software integration will create a foundation for reuse of certified software components and systems. Intelligent Life-Extending Engine Control will yield substantial increases in aircraft engine lifetimes, resulting in reduced life cycle costs for maintaining a fleet of aircraft. Work done previously in the IT program in Intelligent Flight Controls will be extended into Propulsion Controlled Aircraft control laws and demonstrate a capability to adapt to loss of any and all control surfaces resulting from failures

or malfunctions, up to and including propulsion-only flight. This technology can dramatically increase the safety of commercial aircraft. A satellite-based system for air-ground communications using multiple protocols will provide increased situational awareness capability both in the cockpit and on the ground. Research in advanced, high-performance computing will reduce turnaround time for aerospace vehicle design and simulation. The advanced computing system being implemented in the IT Base Program will enable access to distributed computing systems and on-demand connectivity to high data rate instruments, leading to enhanced engineering and scientific collaboration among geographically-dispersed investigators. This technology is likely to impact not only aerospace vehicle design, but also Earth and space science investigations and other applications requiring distributed collaboration, high-end information and computing resources, and access to high data rate instruments. As this system is being developed, software tools will also be developed to accurately predict system performance based on specific computational applications. These optimization tools will provide the capability to extend the dynamic supercomputing system designs, and to provide an evaluation capability for new, innovative supercomputing concepts.

Intelligent Synthesis Environment

The ISE Initiative planning process has followed a three-tiered approach during FY 1999 and the first quarter of FY 2000 :

ISE NASA planning workshop (all NASA Centers, JPL and NASA Headquarters)	Feb. 1999
Government planning workshop for ISE technologies	June 1999
Industry and University workshop for ISE technologies	Oct. 1999

In addition, a large number of technical workshops were held with industry and university participants to establish the state-of-the-art in ISE capabilities and technical working groups were established in each Initiative Element. A Non-Advocate Review (NAR) of ISE was held at end of FY99. The ISE Initiative is coordinating all NASA Centers and NASA's four Enterprises, and is leveraging appropriate activities with other government agencies, the aerospace and non-aerospace industries, computer software and hardware vendors, suppliers, and universities. Pathfinder and pilot studies are being conducted in FY 2000 to identify high-payoff approaches for each of the ISE elements.

When fully developed, ISE will function as a networked collaboration among all geographically dispersed and professionally diverse personnel involved in defining, designing, executing, and operating NASA's missions. The long-term vision is that this collaboration will be in a full-sensory, immersive, virtual environment in which humans and computers can interact through 3-D sight, sound and touch in a computationally rich mission life-cycle simulation. ISE will enable NASA to rapidly assess multiple mission concepts and systems design options and predict total life cycle cost, schedule, risk and performance with much greater accuracy than is currently possible, before proposing or committing funds for development. By FY 2002 ISE will develop an initial set of advanced simulation-based, life-cycle analysis methods, including cost and risk. During FY 2003 ISE will demonstrate an initial integrated, end-to-end multidisciplinary life-cycle design capability for a selected set of ISE applications, with the highest priority on advanced reusable space transportation systems and reduced Shuttle/Space Station operations. By 2004, a new ISE-based approach to integrated science and engineering practice will be demonstrated, enabled by simulation-based engineering knowledge capture and

advanced user interface capabilities in immersive environments.

Aero-Space Vehicle System Technology

In FY 1999, the VST program developed technologies in safety including complete simulations of crew workload displays. They will be used to help reduce accidents caused by human errors in the flight deck. Nondestructive evaluation techniques were developed for improvement in crack detection in thick structures by a factor of two. To enhance environmental compatibility, breakthrough technologies in active structural control that allowed for significant reduction in aircraft bending loads were developed. The VST Program addressed key technology barriers for future subsonic transports. This included developing aircraft controller strategies for enhancing performance and reconfiguration capabilities. Wind tunnel tests were conducted to understand the flow physics and the characterization of abrupt wing stall, an uncommanded, abrupt roll perturbation during elevated load factor turns. Validated design criteria to address the out-of-control "falling-leaf" phenomenon associated with fighter aircraft were provided. The Hyper-X Program continued to support the goals of the Access-to-Space Pillar. Testing setup began on the full-scale model of the Hyper-X vehicle. Comparison of CFD performance prediction and correlation with wind tunnel data also began. In addition, in support of the NASA Safety Initiative, a study was conducted to identify the causes of Controlled Flight into Terrain (CFIT). Based on this study and NRA was issued and thirteen contracts were awarded to develop and demonstrate approaches for fully operational and certifiable synthetic vision (7 awards) and health management (6 awards) systems. Preparation for flight evaluation of a crew-centered synthetic vision display was completed. Also a study that addressed the applicability of synthetic vision to General Aviation type aircraft was completed.

In FY 2000, the VST program will begin a deliberate shift in the focus of the program. The program will maximize the synergism between aeronautics and space transportation. Many of the fundamental technologies have obvious applicability in both these critical areas. The program will continue to develop technology in the areas of safety, environmental compatibility, general aviation, next-generation design tools, experimental aircraft and access to space. To enhance environmental compatibility, technologies will be developed to reduce emissions and drag using smart devices with active components. High-payoff, innovative control concepts will be developed and demonstrated. The BWB drop model test will be completed. Conceptual designs of two advanced configuration aircraft will be completed. High-fidelity multi-disciplinary methods for nonlinear problems will be demonstrated. The first flight test of the HXRV will be completed. Manufacturing methods for the new generation of advanced general aviation aircraft; additional training modules in the flight training curricula, the multifunction display guidelines, a low-cost communications, navigation and surveillance system, and a highly integrated open architecture avionics will be completed.

In FY 2001 the VST program will achieve a healthy balance between activities that contribute to aeronautics and those that contribute to space transportation. The program will continue to develop technology in the areas of safety, environmental compatibility, general aviation, next-generation design tools, experimental aircraft and fully support access to space goals. The program will complete the general aviation activities transferred from the Advanced Subsonic Technology Program including flight testing of the general aviation system concepts and publication of the general aviation standards and methods. Many important tasks will be completed in FY 2001 for space transportation including: extruding near-net sections of Russian Al-Li alloy 1441 for use in space transportation vehicles, the second Mach 7 flight and the Mach 10 flight of the Hyper-X vehicle and identifying protocols and methodologies for accelerated testing of space transportation materials. A key workshop will be held in 2001 to assess

the state of turbulence research and determine future research needs to accurately predict of aerodynamic flow and noise production. New advanced vehicle concepts will be down selected in 2001 and the Blended Wing Body vehicle will pass integration testing and delivery review. Smart actuators will be incorporated into a hingeless Uninhabited Combat Air Vehicle (UCAV) for wind tunnel test this year. Finally, systems analysis will begin on advanced vehicle concepts for a Smart Vehicle System for use by the General Aviation community.

Propulsion and Power

The Propulsion Systems program develops technology that supports all Three Pillars for Success. During FY 1999, the General Aviation Propulsion project began pre-flight ground tests of the intermittent-combustion and turbine engines in preparation for flight demonstrations in FY 2000. Among other activities, advanced material and process systems capable of turbine inlet material temperatures above 2400°F was demonstrated. Work continued on the development of 900°F silicon carbide sensors models, and concepts will be delivered that enable reductions in cost and risk barriers for selected advanced turbine engine components. The High Performance Aircraft project continued active technology validation activities in coordination with DoD. Excellent progress was made in the development of the critical air-breathing launch vehicle component technology, which is scheduled for validation in FY 2000. The effort to improve engine safety also continued with emphasis on development of more crack resistant alloys for blades and disks, and an improved containment system.

During FY 2000, the General Aviation Propulsion project will conduct flight demonstrations of the intermittent-combustion engine and the turbine engine at the Oshkosh Air-show. These flights will demonstrate a new generation of general aviation propulsion systems that are revolutionary in affordability, ease of use, and performance. These new engines, with their smooth, quiet operation, promise to be the key to creating new demand for aircraft and revitalizing the U.S. general aviation industry. The Higher Operating Temperature Propulsion Components project will demonstrate a 900°F silicon carbide sensor in the harsh environment of an engine. If successful, this could lead to development of sensors for many commercial and military applications. Active combustion instability control will form the cornerstone of demonstrating "smart" turbomachinery concepts to minimize pollutants throughout a typical mission. The technology is enabling for stable operations under lean combustion conditions that can potentially lead to as much as 80% NOx reduction in the future. Validation of rocket-based combined cycle (RBCC) propulsion inlet, mixer-combustor, and integrated propulsion pod component is planned, along with the definition of an RBCC propulsion integration technology applications concept for semi-axisymmetric vertical take-off systems for access to space. A new effort to establish the feasibility of pulse detonation-based technologies to hybrid-cycle and combined cycle propulsion systems for meeting the aviation and access to space goals will be initiated. The effort to improve engine safety will continue to seek alloys for blades and disks, which are more crack-resistant for delivery in FY 2001. The fundamental aspects of noise generation and propagation, and the identification of advanced noise reduction concepts will continue. This activity will provide enabling capabilities for new, high-risk, high-payoff technologies that are of long term strategic importance in noise reduction. A new 2-stage low tip speed fan with swept stator vanes design which will significantly reduce fan noise will be completed. The Zero CO_2 Research project will be initiated. This project is focused on identifying the technologies needed to drastically reduce or eliminate CO_2 emissions from civil transport aircraft.

During FY 2001, the effort to improve engine safety will continue. The Ultra Safe Propulsion will continue with the development of an improved containment system. An assessment and conceptual design of pulse detonation engine-based hybrid cycle and combined cycle propulsion systems will be completed. Pulse detonation engines offer many advantages over conventional gas turbine engines that make them very attractive for subsonic, supersonic and access to space applications. NASA will complete an inlet test in support of the development of pure pulse detonation engines for military applications. Oil free technology will be a major step in the further reduction of engine acquisition and life cycle costs of general aviation along with increased reliability through the removal of one of the most maintenance intense systems on the engine. A complete core hot section oil-free radial foil bearing will be tested in a rig in FY 2001. An analysis of a liquid hydrogen optimized engine and airframe will be completed in support of the Zero CO_2 Research project. Hydrogen-fueled engines, as a substitute to hydrocarbon fuels, can curtail CO_2 emissions by reacting with the oxygen in the atmosphere to produce water but no CO or CO_2 byproducts. The permeability of lightweight polymer composite liquid hydrogen tanks will be determined. Reduction of the hydrogen permeability of polymer matrix composite tanks may allow the safe and efficient storage of low density liquid hydrogen in commercial transport aircraft. New energy conversion technologies will also be investigated. The fracture toughness of solid oxide fuel cell electrolytes for high pressure hydrogen/air fuel cells will be determined. The fundamental aspects of noise generation and propagation, and the identification of advanced noise reduction concepts will continue. Jet noise models which improve acoustic analogy models through gaining insight into flow physics and leading to ever quieter propulsion systems will be developed.

Flight Research

During FY 1999, the Flight Research program continued to develop high altitude, long-duration, uncrewed flight concepts through ERAST, including the demonstration of multistage turbocharged RPA to 60,000 feet for an 8-hour duration. A demonstration of an RPA for 4 hours above 55,000 ft was also accomplished. The Centurion solar-powered airplane, a vehicle with a wingspan greater than 200 ft., completed initial low altitude evaluation under battery power. This RPA technology will increase the Nation's capability to make scientific subsonic sampling high in the stratoshpere. In pursuit of improved aviation safety, the effort to help transition technology into use by the air transportation industry was completed. The Aviation Safety Flight Integration Plan draws technology from the other program elements, and make use of available aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, an F-18 testbed aircraft is being modified to investigate Active Aeroelastic Wing (AAW) technology in preparation for the flight tests, which will begin in FY 2002. Under advanced concepts, the PHYSX test program, a Pegasus launch vehicle with a wing glove fixture measured the cross-flow boundary layer at hypersonic (Mach 8) speed, providing critical design data for vehicles that will provide access to space. The flight experiment was flown in November 1998 and was completely successful.

The Flight Research program in FY 2000 will be developing further capability for increased altitude using ERAST remotely piloted airplanes (RPA). The Centurion solar-powered RPA designed for flight to 100,000 feet will be modified to a wingspan configuration of greater than 245 ft., in a new prototype called Helios. This configuration will be more suitable for extreme endurance as well as flights to 100,000 ft. It will be demonstrated and ready for later upgrade to high-efficiency solar cells and maximum altitude and duration missions. In pursuit of efficiency and affordability, an F-18 testbed aircraft will continue its modification to investigate Active Aeroelastic Wing (AAW) technology. A new effort will be initiated under the X-plane goal, but with applicability to a number of the other goals. Under the name revolutionary concepts, or REVCON, the design and development of a blended wing body sub-scale

X-plane will be initiated. This X-plane will be dropped at high altitude from under the wing of the B-52, with the objective of obtaining flight test data on the transonic characteristics of the revolutionary concept. With the first flight in 2001, the new shape is expected to offer major contributions to the goals of increased capacity, reduced emissions, increased throughput and increased mobility. REVCON also includes the development of a Pulse Detonation Engine (PDE), a revolutionary air-breathing jet that utilizes constant volume thermodynamic cycle to be tested on the SR-71 testbed. Under the reduced emissions goal, the advanced flight concepts will explore use of precision formation flight in order to reduce overall drag, and consequently reduce fuel burn. The concept will be demonstrated with two F-18 aircraft and autonomous formation flight system.

In FY 2001 the Flight Research program will demonstrate a solar powered RPA at 100,000 ft and complete development of a heavyweight energy storage system under the ERAST project. Both achievements will demonstrate technologies that will provide atmospheric satellites for commercial use and create the Nation's capability to make scientific subsonic sampling high in thestratosphere. The Revolutionary Concepts (REVCON), a new project started in FY 2000, accelerates the exploration of high-risk, breakthrough technologies in order to enable revolutionary departures from traditional approaches to air vehicle design. The first NRA under REVCON will down select to an implementation phase in FY 2000. Within REVCON the development of a PDE inlet, a revolutionary air-breathing jet propulsion concept utilizing constant volume thermodynamic cycle, will be completed. In pursuit of efficiency and affordability, an F-18 testbed aircraft will complete its modified and systems checkout in preparation of FY 20002 flights to investigate Active Aeroelastic Wing (AAW) technology. Within the Innovative Transport and Testbed Experiments and the Atmospheric Flight of Space Systems aerospace synergy supporting both safety and affordability will be demonstrated in the area of vehicle health management. Efforts in the area of structure health management and propulsion health management will be investigated, concentrating on optical sensors, engine sensors, and detection algorithms. Within the Advanced Systems Concepts, investigations into technology to advance Uninhabited Air Vehicles will continue, with the development of robust autonomous taxi capability.

Operations Systems

During FY 1999, the Aviation Operations System program was re-planned to respond to the President's safety goal of reducing aviation accidents by 5 fold in 10 years. A model of human memory constraints in procedure execution and reactive planning will be developed. This model will be used to guide design of automation to aid air traffic service providers, airline operations center personnel and flight crews to assure automation support consistent with human performance characteristics. Working with industry, the program continued to improve the effectiveness of ice protection systems and reduced development and certification cycle & costs for industry. International collaboration, needed for dramatic improvements in aviation safety, was strengthened by a joint Super-cooled Large Droplet (SLD) icing research conducted with AES (Atmospheric Environment Sciences) of Canada. To enhance safety, an increased emphasis was put on the development of procedures and innovations to clarify the roles and responsibilities of aircraft maintenance teams. In addition, to reduce weather related accidents, systems for communicating and displaying real time weather information to airborne and ground base users were pursued in collaboration with industry and DoD, FAA and NOAA/NWS through NASA Research Announcements. Multiple advanced weather information systems were developed, evaluated and demonstrated for providing graphical weather information in the flight deck. These systems were demonstrated with various packaged weather products using satcom broadcast, cellular phone and ground based 2 way broadcast infrastructure. The

weather products included turbulence, weather radar (US only) satellite, and convective detection warnings. Rapid prototyping led to flight evaluations on a Cessna Citation, USAF C-135, FedEx Cessna Caravan and numerous general aviation aircraft.

During 2000, the Aviation Operations System program will continue its focus on developing more basic concepts, procedures and systems to remove the key barriers to significant improvements to the safety of the nation's aviation system. Fundamental modeling of human performance will incorporate visual motion and eye movement parameters in computational models of human vision. Automation system functional model decomposition methods are being matched to human performance constraints and biases. The result is a theory-based methodology for predicting operational error-vulnerability. This method will be empirically validated through a representative safety analysis for air-ground automation and operational procedures. Ultimately this will result in a computational model matching human/system performance and error trends.

For FY 2001, the focus of the program will be on technologies in areas emphasized as important by the Aero-Space Technical Advisory Committee (ASTAC), subcommittee for Aerospace Operations Systems. The two primary areas are weather (icing research) and training/countermeasures. Icing research will continue to be conducted, with primary emphasis on the development of a ground-based sensor suite to assist in detecting icing conditions. Training research, which is a new thrust, will concentrate on developing an understanding of the causes of errors during concurrent task management, with an eye toward later development of training tools to alleviate this type of error.

Rotorcraft

In FY 1999, the Rotorcraft program completed the integration of new basic physics knowledge with advanced, information technology tools to provide accurate, flexible modules suitable for use by industry in their integrated design systems. A new emphasis aimed at thick composite structures has reduced parts count and the cost of rotorcraft. Noise reduction work was performed in three areas: more effective noise reduction technologies for the rotor, both passive and active; additional attention to the reduction of power-train noise and vibration; and the assessment of operations that minimize noise impact on the ground, including the development of codes that can be used by community planners and airport operators. New innovative rotorcraft flight concepts were supported through technical cooperation with DOD and industry. Testing of baseline rotorcraft helical gear train configurations, to establish minimum lubrication conditions while maintaining ultra-safe operations, was completed.

Gear-crack propagation analysis tools, as well as specific gear experiments were used to develop three-dimensional (3D) boundary element/fracture mechanics analyses. Full-scale experiments were completed, validating conditions where two-dimensional (2D) analysis is accurate. Expanding on the key findings of the accident analyses, new efforts were initiated with helicopter operators and manufacturers to target near-term opportunities for accident reduction.

In recognition of the critical role that loss of situation awareness has played in previous fatal accidents, methods of measuring and predicting situation awareness was demonstrated in part-task simulation and efforts to improve detection and avoidance of obstacles, such as wires and poles, was initiated. During its fourth year, the NRTC has continued to focus on near-term opportunities to reduce and improve performance and increase activities in flight safety and reliability. The NRTC has coordinated projects in conjunction with alliances among the FAA, DOD, NASA and industry to assess near-term national needs with a view to

maximize leverage of the NASA investment while minimizing duplication. Completing the flight evaluation of Differential Global Positioning System (DGPS) coupled to heliport precision-instrument approach has enabled a quantum improvement in integrating rotorcraft into the evolving transportation infrastructure. Demonstrating the structural characteristics of hybrid titanium/graphite-composite structures has provided for improved safety and affordability in engine compartments and other high temperature areas.

In FY 2000, the Rotorcraft program will conduct wind tunnel in conjunction with advanced active control research to reduce vibration, noise and improve performance. Building on the earlier fatigue life prediction of composite structure work, analytical and experimental techniques for tail rotor flexbeams will be established. Upon completion of evaluations of a number of innovative active and passive noise and vibration reduction concepts, the most promising techniques will be chosen for further research. Efforts to model the full flight vehicle for development of noise-abatement procedures will continue.

Accurate, flexible analysis modules suitable for use by industry in their integrated design systems will be completed. Rotorcraft safety will be emphasized through the development and evaluation of health and usage monitoring systems and predictive technologies. Methods of predicting and measuring pilot situation awareness will be developed and tested to allow designers the take this key factor into account when designing new systems. Using the situation awareness prediction model the effectiveness of new displays, and other pilot interface technologies for improving pilot situation awareness, will be studied. Specifications for the hardware and format of a cockpit display designed to improve pilot situation awareness will be completed. The NRTC solutions of industry-wide problems will benefit the performance, utility and public acceptance of both helicopters and tilt-rotor concepts. The developed technologies will improve flight-safety with health-management systems, enhance design/manufacture compatibility, and alleviate both interior and exterior noise. Flight safety will be addressed by continued development of crashworthy design methodologies that account for crash/hard landing on various surfaces, with delivery of completed milestone in FY 2001.

In 2001, the Rotorcraft Program will conduct a vigorous effort to develop technology and transfer it to industry through the FRIAR project, implemented through the National Rotorcraft Program and the Rotorcraft Industry Technology Association. There will be advances made in the areas of crashworthiness of Rotorcraft which will demonstrate advances to mitigate damage to airframe structures due to crash/harsh landings onto both soft and hard surfaces such as soil, concrete, or water. To improve flight safety and lessen the cost of maintenance, new HUMS (Health and Usage Monitoring Systems) protocols will be developed. HUMS will track wear and tear on critical parts as well as sense deterioration and give warnings. Plans for limited flight evaluations acceptable to both DoD and FAA will be developed. In the area of design tools for rapid prototyping, there will be a demonstration conducted for the new "express-tool" technology. This can reduce design to fabrication time by 50% where it is applied to complicated parts and assemblies. The SAFOR project is in close coordination with the FRIAR project and will deliver a Ultra-Safe Gear Design Guide to be published in FY 2001. This will conclude the provision of ultra-safe gear technology, which has been demonstrated in FY 2000 through testing and correlation with design tools, under the FRIAR Project. Under the FRIAR Project, in the area of Composite Structures Technology for Rotorcraft, a certification methodology will be delivered for inclusion in Military Standard Handbook 17. Under the DEAR Project, also in the Composite Structures Technology for Rotorcraft, aimed at provision of a new physics-based design tool for composite structures for Rotorcraft Airframes, a technology for prediction of stringer/skin separation mode of failure will be provided. Finally, under the SAFOR Project flight tests will be completed that demonstrates and validates control laws for low pilot workload under typical civil operations involving low visibility weather conditions.

Space Transfer and Launch Technology

In FY 1999, the STLT program completed several key Earth-to-orbit technology demonstrations. These included: the full duration firing of the Fastrac rocket engine which will power the X-34 experimental vehicle (1999 NASA Continuous Improvement Award Recipient); fabrication of a 250,000 lb.-thrust pressure-fed hybrid motor; the completion of the 1st phase of rocket-based combined-cycle flowpath testing with Aerojet and Rocketdyne engine concepts; and a proof of concept demonstration of a 50 ft. MagLev launch assist track which is the next step towards an operational launch assist capability.

In addition, the STLT program participated in the development of a long-term plan for Earth-to-orbit technologies, called Spaceliner 100. Spaceliner 100 provides a blueprint for future investments, which will dramatically increase the safety, reliability and decrease the cost of future transportation. While Spaceliner is focused on 3rd generation needs, many of the technologies will provide a direct benefit for 2nd generation launch systems. In FY 1999, NASA canceled the Bantam activity and directed tasks and resources towards Spaceliner identified needs.

The STLT program also completed several in-space technology demonstrations. These included including the successful performance of the NSTAR ion engine on the DS-1 mission, development and test of key non-toxic orbital propulsion components, test of a long duration, on-orbit cryogenic storage system and facilitation of an independent in-space propulsion planning activity. Research highlights included: hosting of the 10th Annual American Institute of Aeronautics and Astronautics Propulsion Workshop; completion of beamed power proof of concept demonstrations to altitudes of 125 ft using a 10kW laser; and the award of six Breakthrough Propulsion Physics activities in a wide range of topics, including experiments related to superconductor-gravity effects and verification of faster-than-light hypotheses. In FY1999, the Aero-Space Technology Program was integrated into the Aero-Space Base Research and Technology Program in order to fully leverage Aero-Space synergy.

In FY 2000, the STLT program will demonstrate several key Earth-to-orbit technologies. These include: delivery of a flight-certified Fastrac engine to the X-34 Program; development of a composite liquid oxygen tank for the X-34; development of a PETI-5 (high temperature material developed in the High Speed Research Program) composite wing for the X-37; ground test of the Ultra-Low-Cost Engine; extension of the MagLev track to 400 ft in length; downselection of a preferred airbreathing propulsion testbed approach; completion of liquid oxygen densifier verification testing and completion of hydrogen densifier fabrication; completion and test of advanced metallic reentry thermal protection system materials; and fabrication of composite rocket thrust cell chamber demonstration unit. Tasks originally initiated under the Bantam activity have been realigned with Spaceliner needs and include tasks such as advanced materials, advanced composite cryogenic tank development, high temperature thermal protection systems, and advanced control systems. A new Integrated Vehicle Health Management (IVHM) Project has been initiated to provide focus for this diverse discipline. The IVHM Project is a multi-year effort that will culminate in IVHM system-level technology and operations demonstrations using a virtual IVHM Testbed. Planned in-space demonstrations include completion of NSTAR ground engine testing and completion of the 500 hours of test on a 10kW hall thruster. In FY 2000, Space Transportation Research activities will be guided by peer review of the most promising breakthrough concepts and will continue to pursue propulsion concepts that have the potential for interstellar travel. Work on 3rd generation RLV technologies, also known as Spaceliner 100, will continue, although emphasis has principally shifted to 2nd generation RLV technologies.

Trade studies were also initiated to define the cost and capability of an advanced airbreathing test facility necessary to address requirements generated by Advanced Space Transportation Program. Contractors will be selected to initiate detail designs and specifications of the major systems such as propellant and pressurization systems, air storage and delivery, thrust measurement, instrumentation and control systems.

FY 2001 activities will be consistent with the Integrated Space Transportation Plan and guided by comprehensive systems analysis. 2nd Generation RLV technology investments will be strongly driven by industry needs and may include: component and subsystem demonstrations for composite materials and tank systems; ceramic and metallic thermal protection systems; continuation of cooperative partnerships with the DoD for the integrated powerhead rocket engine demonstration; low-cost rocket engine turbomachinery and injector concepts; lightweight valves, lines and ducts; long-life materials; robust sensors; advanced energy sources; microavionics; autonomous flight control and mission planning; low-cost range systems; completion of propellant densification testbeds; automated umbilicals; and containerized payloads. In-space investments include low-cost upper stage, Earth orbital, planetary and interstellar transfer technologies. Upper-stage technologies are focused on advanced peroxide based systems and will demonstrate advanced components (including catalyst beds and materials testing) and engine systems, including cooperative participation with the DoD on the upper stage flight experiment. Earth orbital and planetary investments will focus on the development of high-performance, lightweight propulsion technologies, including solar electric transfer, lightweight feed system components, planetary aeroassist and on-orbit cryogenic fluid management. Interstellar precursor technology development will focus on development of lightweight solar sail materials. Propulsion activities include the development of a long life / lightweight rocket engine testbed and an airbreathing propulsion testbed. Airbreathing activities will include technologies that support hydrogen and hydocarbon concepts in both a vertical and horizontal takeoff mode throughout the speed range. Crosscutting technologies will be pursued which support both rocket and airbreathing concepts, such as long life turbomachinery, revolutionary materials and smart sensors. Other Advanced Launch Technology investments include: development of rapid design and analysis tools; continued development of MagLev launch assist; low-drag aerodynamic structures; SHARP ultra-high-temperature ceramic materials; integrated smart/adaptive thermal-structures; morphing structures; drag modulation through electromagnetics and flow physics; adaptive intelligent systems; adaptive self-diagnosing/self-healing thermal protection systems; structurally integrated, wireless; micro/nano sensors and avionics; regenerative sensors; and autonomous/adaptive control and technologies for spaceport /range operations. Research activities will continue to be guided by concepts that have the potential for enabling future generations of RLV's and in-space transportation.

The advanced airbreathing test facility activities will be focused on the preliminary design review (PDR). This will be used to finalize the requirements, design approach and major procurements. All civil and site work is to be completed in FY 2001 and activities will be initiated on all ancillary systems.

The Space Transportation Architecture Phase III Study and subsequent planning efforts in 1999 and 2000 provided industry and government with an assessment of the type of reusable systems and architectures required to address an initial set of NASA and industry requirements. The initial definition of requirements and architectures allowed NASA to establish an Integrated Space Transportation Investment Plan and provide a comprehensive recommendation to the Administration for achieving increased safety, reliability and affordability goals for future RLV systems. Key to this activity was the identification and prioritization of technologies that are critical to reducing the technical risk sufficient for industry to commit to a commercial RLV system. The Space

Transportation Architecture studies concluded that the highest priority areas for technology investment are Crew Survivability, main propulsion, integrated structures and reliable subsystems. NASA expects that these priorities will remain the key focus of 2nd generation technology efforts and will be the basis of industry risk reduction activities.

This effort also established a significant pre-cursor activity to the FY 2001 Systems Engineering and Requirements Definition task within the 2nd Generation RLV program. With the completion of the Integrated Space Transportation Plan, industry and government efforts began to address the critical elements of technical risk reduction and NASA unique requirements that are essential to achieving convergence with commercial RLV systems. This effort successfully combined industry and government resources and capabilities, which provided for the maximum use of new and existing RLV tools, models and methods.

BASIS OF FY 2001 FUNDING REQUIREMENT

AERO-SPACE FOCUSED PROGRAMS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
High-Performance Computing and Communications	20,600	24,200	24,200
High-Speed Research	180,700	---	---
Advanced Subsonic Technology	89,620	---	---
Aviation System Capacity	53,888	62,929	59,200
Aviation Safety	---	64,394	70,000
Ultra Efficient Engine Technology	---	68,306	35,000
Small Air Transport System	---	---	9,000
Quiet Aircraft Technology Program	---	---	20,000
2nd Generation RLV	365,299	183,400	290,000
Total	710,107	403,229	507,400

NASA's Aero-space focused programs address national needs, clearly defined customer requirements and deliverables, critical program decision and completion dates, and a specified class of research with potential application. Each of the focused programs is discussed in detail on the following pages.

BASIS OF FY 2001 FUNDING REQUIREMENT

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
		(Thousands of Dollars)	
High-Performance Computing and Communications	20,600	24,200	24,200

PROGRAM GOALS

The main objective of the Federal HPCC R&D programs is to extend U.S. technological leadership in high performance computing and computer communications. As this is accomplished, these technologies will be widely disseminated to accelerate the pace of innovation and improve national economic competitiveness, national security, education, health care, and the global environment. NASA's HPCC Program is a key contributor to four of the five current federal program component areas:

- High End Computing and Computation
- Large Scale Networking, including the Next Generation Internet
- Human Centered Systems
- Education, Training, and Human Resources

NASA's primary contribution to the Federal program is its leadership in the development of algorithms and software for high-end computing and communication systems which will increase system effectiveness and reliability, as well as support the deployment of high-performance, interoperable, and portable computational tools. As HPCC technologies are developed, NASA will use them to address aerospace transportation systems, Earth sciences, and space sciences research challenges. NASA's specific research challenges include improving the design and operation of advanced aerospace transportation systems, increasing scientists' abilities to model the Earth's climate and predict global environmental trends, further our understanding of our cosmic origins and destiny, and improving the capabilities of advanced spacecraft to explore the Earth and solar system. The HPCC Program supports research, development, and prototyping of technology and tools for education, with a focus on making NASA's data and knowledge accessible to America's students. These challenges require significant increases in computational power, network speed, and the system software required to make these resources effective in real-world science and engineering environments.

In support of these objectives, the NASA HPCC Program develops, demonstrates, and prototypes advanced technology concepts and methodologies, provides validated tools and techniques, and responds quickly to critical national issues. As technologies mature, the NASA HPCC Program facilitates the infusion of key technologies into NASA missions activities, the national engineering, science

and education communities, and makes these technologies available to the American public. The Program is conducted in cooperation with other U.S. Government programs, U.S. industry, and the academic community.

STRATEGY FOR ACHIEVING GOALS

1) Infuse HPCCP technologies in to mission critical stakeholder Enterprise/Office processes, and document discernable improvements in the stakeholders' processes and, if possible, final products as a result of the use of HPCCP technologies.
2) Increase the computer and communication performance available for use in meeting NASA mission requirements.
3) Increase the interoperability of application and system software operating on high performance computing and communications systems available for use in meeting NASA mission requirements
4) Improve the portability of application software and data to new or reconfigured high performance computing and communications systems available for use in meeting NASA mission requirements.
5) Improve the reliability of user-requested events executing on high performance computing and communication systems available for use in meeting NASA mission requirements.
6) Improve the ability to manage heterogeneous and distributed high performance computing, storage, and networking resources available for use in meeting NASA mission requirements.
7) Improve the usability of high performance computing and communications tools and techniques available for use in meeting NASA mission requirements.

HPCC is a computing and communications research program that pursues technologies at various levels of maturity. Applications in the areas of Earth science, space science, aero-space technology, and education are used as drivers of HPCC's computational and communication technology research, providing the requirements context for the work that is done.

As a cross-cutting multi-enterprise initiative, the HPCC Program receives funds from the Aero-Space Technology (AT), Space Science (SS), and Earth Science (ES) Enterprises, and the Office of Human Resources and Education.

The HPCC Program is coordinated through the Aero-Space Technology Enterprise and is managed by NASA Ames Research Center. The Program has supporting work at nine other NASA field centers and the Jet Propulsion Laboratory (JPL) and is organized into five Projects:

- Computational Aerospace Sciences (CAS)
- Earth & Space Sciences (ESS)
- Remote Exploration and Experimentation (REE)
- Learning Technologies (LT)
- NASA Research and Education Network (NREN)

	FY 1999	FY 2000	FY 2001
Aero-space technology	20,600	24,200	24,200
Earth Science	14,500	21,900	21,800
Space Science	8,400	19,500	24,900
Education Programs	4,000	4,000	4,000
			0
Total direct HPCC (NASA-wide)	47,500	69,600	74,900

The following discussion describes the projects managed by the Office of Aero-Space Technology.

Computational Aerospace Sciences

The CAS Project facilities the transfer of technology developed in NASA aerospace and information technology research efforts to routine use by operationally-oriented or product-oriented programs within the NASA Aero-Space Technology Enterprise. This will provide the aerospace community with key tools necessary to reduce design cycle times and increase fidelity in order to improve the safety, efficiency, and capability of future aerospace vehicles and systems. This has the additional benefit of establishing within the aerospace community a viable market for vendors of high performance computing hardware and software. CAS, because of this relationship with the general computer science community, provides input and direction for developing technology for aerospace application.

The CAS Project works with NASA Aero-Space Technology Enterprise Programs and the extended aerospace community to select high priority areas that have bottlenecks or limits that could be addressed through the application of high end computing. These challenging, customer-focused applications guide efforts on advancing aerospace algorithms and applications, system software, and computing machinery. These advances are then combined to demonstrate significant improvements in overall system performance and capability.

NASA Research and Education Network

The goal of the NASA Research and Education Network (NREN) Project is to provide a next generation network testbed that fuses new technologies into NASA mission applications. The capabilities that are realized by these new technologies will enable new methodologies for achieving NASA science goals. Moreover, these networking technologies will provide NASA missions with the advantages of enhanced data sharing, interactive collaboration, visualization and remote instrumentation. NREN will meet these goals through technology integration and collaborations within the multi-agency Next Generation Internet program.

The NASA Research and Education Network (NREN) Project is NASA's part of the Federal Next Generation Internet (NGI) initiative. The Next Generation Internet initiative is a multi-agency Federal partnership with industry and academia to develop significantly higher performance networking technologies and systems enabling next-generation distributed applications between scientists, engineers, and computing resources.

SCHEDULE AND OUTPUTS

Demonstrate 200-fold improvement over FY 92 baseline in time to solution for Grand Challenge application on TeraFLOP testbeds. Plan: June 1999 Actual: June 1999	Demonstrated 200 – fold improvement in time to solution utilizing a full combustor simulation
Demonstrate 500 times end-to-end performance improvement of Grand Challenge and/or NASA mission applications based on FY 96 performance measurements across NASA NREN testbeds over 622 Mbps wide area network. Plan: March 2000	Perform at least three demonstrations at 500 times more end-to-end performance improvement over FY 96 baseline. Additional time is required to address the newly selected NASA applications.
Establish an international Next-Generation Internet eXchange (NGIX) Plan: January 2000	Demonstrate connectivity across an international Next-Generation Internet eXchange.
Demonstrate multicast and quality of service (QoS) technology in a hybrid networking environment Plan: June 2000	Provide at least two demonstrations of multicast and QoS technology in a hybrid (wireless and ground) networking environment.
Demonstrate time-to solution improvements for grand challenge applications on HPCC testbeds Plan: September 2000	Demonstrate at least a 400-fold improvement over 1992 baseline in time-to-solution for one grand challenge application in the area of computational aerosciences.

Develop system software tools and techniques to enhance application performance Plan: June 2001	Software tools to reduce parallelization time from months to one week while maintaining 50% application performance compared with manual parallelization.
Develop tools and techniques to measure computing and communication capabilities Plan: September 2001	Tools to benchmark testbed performance in computing capability, database manipulation, and scheduling to evaluate alternate scheduling strategies and chose optimal approaches to reduce variability and improve predictability of turnaround time. Automated quality of service data collection tool for networks capable of measuring 2 service classes and scalable to at least 5 nodes.
Adapt application codes for high performance testbeds Plan: September 2001	3 relevant application codes parallelized; 3 data analysis codes parallelized; documented evaluation of parallelization tools. 3X performance in applications for aerospace through the integration of networking enhancements into application codes.
Demonstrate advanced networking tools and techniques on NASA mission-oriented applications Plan: September 2001	3 applications inter-operating on multiple QoS enabled networks; 50Mbps (aggregate internal) multicast; gigabit performance between 2 NASA sites; 2 applications utilizing enhanced hybrid networking.

ACCOMPLISHMENTS AND PLANS

In FY 1999, CAS demonstrated improvement in the time-to-solution for Grand Challenge applications using a newly-installed testbed. CAS applications exceeded the goal of performing at 200 times the established baselines. This activity was also supported by NREN/NGI technologies through NREN goals of enabling network-intensive applications. NREN addressed specific applications both relevant to NASA missions and providing the pacing requirements for further networking research and implementation.

While continuing to use high-end computing systems, CAS initiated more in-depth efforts to develop computational grids and increased its work on computational grid concepts through expanded collaborations with academia, NSF, and DARPA. The prototyping of a computational grid will seamlessly link NASA resources—computers, data, instruments, and people—into an interdisciplinary problem-solving and decision-making environment. This effort is driven by: (1) NASA requirements to make more effective and coordinated use of existing and future computational assets, and (2) the need for collaboration among individual groups that are using advances in software technology to develop sophisticated problem solving systems. By recognizing the similarity in the underlying approaches to meeting these needs, an overall system can be developed that provides an improved environment for resource management, while at the same time providing a uniform architecture for software development—from systems software (including security, resource management, etc.) to the domain applications.

In FY 2000, CAS will continue to improve time-to-solution for relevant applications while implementing initial software to demonstrate a prototype distributed high-performance testbed (computational grid). Along with the installation of HPCC's Earth

and Space Science testbed, the CAS computational grid testbed will provide the vital computing resources required to achieve 1,000-fold improvements over established baselines. NREN will demonstrate applications that demand high-performance network capabilities, in some cases focusing its research on the same applications as CAS and ESS. NREN efforts will focus on the development and testing of mechanisms for scheduling guaranteed network quality of service to meet real-time bandwidth, latency and error tolerance requirements. This vital work supporting Next Generation Internet (NGI) will increase the quality, security and certainty of Internet transmissions and on the network capable of 1,000 times the capacity of the baseline.

In FY 2001, CAS will demonstrate 1,000-fold improvements over FY 1992 baseline in time to solution for relevant applications on high performance computing testbeds. These performance improvements will be partially supported through the demonstration of new software tools to benchmark testbed computing performance, database manipulation, and resources scheduling. In addition, CAS will complete the development of software tools to dramatically reduce parallelization time for high performance systems. Ultimately, the FY2001 accomplishments by CAS will allow for complete aircraft engine combustor and compressor simulation in three hours each, high-fidelity space transportation vehicle analysis in one week and the database generation for stability and contorls of aerospace vehicles within one week. CAS will demonstrate these capabilities on four NASA aerospace vehicle design activities. During this same time period, NREN will be providing the capability to monitor and benchmark performance of high-end networks, tools to enhance applications performance through the integration of networking enhancement into applications codes, and demonstrations of interoperation among high performance NASA and NGI networks.

BASIS OF FY 2001 FUNDING REQUIREMENT

HIGH-SPEED RESEARCH

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
High-speed research	180,700	---	---

PROGRAM GOALS

NASA's High-Speed Research (HSR) program goal was to develop the technologies that industry needed to design and build an environmentally compatible and economically competitive HSCT for the 21st century available to enable an industry decision on aircraft production. As originally envisioned, an HSCT aircraft would carry 300 passengers at Mach 2.4 on transoceanic routes over distances up to 6,000 nautical miles at fares comparable to subsonic transports.

STRATEGY FOR ACHIEVING GOALS

In the early 1990's, studies indicated that an environmentally compatible and economically competitive HSCT could be possible through aggressive technology development. Since then, NASA concentrated its investments in the pre-competitive, high-risk technologies. While NASA has continued to be successful and is on track to meet the original program goals, recent market analyses and estimated industry development costs of $15 to $18 billion have made the HSCT considerably less attractive to NASA's industry partners. Cost of development in this amount puts the aircraft industry at significant financial risk. Current analyses indicate that further significant investments in technology development are required to ensure an economically viable HSCT. Consequently, the cost of development has led the major aircraft manufacturer to the conclusion that the introduction of an HSCT cannot reasonably occur prior to the year 2020. For these reasons, industry has reduced their commitment to this area and has scaled back their investments. Given other pressing needs in the Agency in general and aeronautics in particular, the HSR program was concluded at the end of FY 1999.

SCHEDULE AND OUTPUTS

Subcomponent Test Data (Materials and Structures). Plan: March 1999 Actual: September 1999	All data acquired during wing subcomponent testing and during seven fuselage subcomponent tests and four fuselage subcomponent tests have been compiled and released.

Component Materials Selection. Plan: March 1999 Actual: February 1999	M&S concepts were selected for wing component test article. M&S concepts for fuselage component test articles were selected. Selections are based on material performance and structural efficiency and uses analyses and test data.
Phase II Assessment of Atmospheric Impact. Plan: February 1999 Actual: February 1999	The assessment of environmental compatibility of HSCT incorporating HSR emissions reduction technology was completed and report issued, including the results from engine emissions characterizations, near field iterations, and operational scenarios applied to global chemistry and transport models, which were validated with laboratory studies and stratospheric atmospheric observations.
Full Scale Design Build 1 Designed; Plan: March 1999 Actual: Deleted	Due to program termination, the nozzle design effect was terminated after the Conceptual Design Review (CDR) in June1999. The preliminary and detailed design efforts will not be initiated nor completed.
1-Lifetime Accelerated Test Data. Plan: June 1999 Actual: July 1999	1-lifetime of data acquired during accelerated thermal-mechanical-fatigue testing of materials was compiled and released for use in validating analytical methods for predicting material degradation.
Full Scale Annular Combustor, Rig, and Liner Design - Configuration/Materials Plan: September 1999 Actual: Deleted	Complete detailed design of the selected HSCT scale combustor and life prediction analysis for the liner. Design temperatures and stresses in the liner are within the capabilities of the EPM developed material. Drawings are released for fabrication. Due to re-planning for termination of this program, the work toward this milestone was terminated.
Program Technologies Documented Plan: September 1999 Actual: November 1999	In-depth documentation of HSR Phase II technologies incorporated in the HSR Technology Concept Level 1 milestone of December 1998 was completed along with a concise summary of lessons learned in HSR work. Technology advances achieved in the HSR program will be appropriately integrated into ongoing and planned NASA programs where data restrictions allow.

ACCOMPLISHMENTS AND PLANS

As part of a planned orderly closeout at the end of FY 1999, the following activities were concluded: completed TIFS flight tests for external vision validation and validate a display, guidance, and control system; completed airframe materials durability composite database under isothermal without load; completed all subcomponent testing and analysis and thermo-mechanical fatigue tests of thick laminate joints; completed interim fabrication database of PETI-5; completed half-span aeroelastic test in LaRC Transonic Dynamics Tunnel, completed high-lift configuration evaluation; completed high-speed performance validation; complete an assessment of the environmental compatibility of the HSCT incorporating new emissions reduction technology; completed combustion environment testing of Ceramic Matrix Composite (CMC) liner parts for ultra low emissions combustor; competed

conceptual design of full scale technology demonstrator nozzle; completed digital assessments of innovative ultra low noise nozzle concept, provided improved aeroacoustic scaling methodologies; completed initial assessment of "waverider " inlet concept; completed scale-up feasibility effects of nozzle advanced materials (superalloy);complete d nozzle materials characterization studies; completed down-selection process for turbomachinery disk and turbine alloy materials; completed a technology identification study to meet new requirements for "Lessons Learned" documentation; completed summary and lessons learned documentation for all technology areas for transfer, as appropriate, to other focused programs and base activities.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED SUBSONIC TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Advanced subsonic technology	89,620	---	---

PROGRAM GOALS

The goal of NASA's Advanced Subsonic Technology (AST) program was to develop high-payoff technologies, in cooperation with the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the civil aviation industry's international competitiveness and the public. These technologies were aimed at reducing travel costs while increasing safety, reducing civil aircraft impact on the environment, and increasing doorstep-to-destination travel speeds. The success of the AST program has resulted in significant contributions to technology readiness that will preserve our Nation's economic health and the welfare of the traveling public, and mobility and accessibility to more destinations in the national air transportation system.

STRATEGY FOR ACHIEVING GOALS

To focus resources on high priority national goals like aircraft engine emissions and airport crowding, the AST program was concluded in FY 1999. The AST program has been successful and progress was made toward meeting the current program goals. Aggressive technology transition plans have been pursued in order to mitigate the significant risk to successful technology transfer to industry as a result of early termination.

In order to continue progress toward the planned AST program goals in Noise Reduction and General Aviation the current technology development projects in these areas was transferred to the Airframe Systems Research and Technology Base program. This will result in these AST goals being accomplished as planned. In addition, key technology developments in the areas of Emissions Reduction and Environmental Assessment were transitioned to the Ultra-Efficient Engine Technology (UEET) program as required to meet UEET objectives.

SCHEDULE AND OUTPUTS

Enviornment

Emissions Reduction: Demonstrate reduction of future large engine emissions of NOx by 50 percent. Plan: September 1999 Actual: September 1999	The ability of the AST low emission combustor to achieve to reduce NOx levels 50 % below the 1996 ICAO regulations were demonstrated with the combustor installed in a PW 40000 development engine.
Environmental Assessment: UNEP/WMO Ozone/IPCC climate reports input. Plan: September 1999 Actual: September 1999	The second program-level assessment report was completed in preparation for the 2000 UNEP/WMO ozone and IPCC climate assessment report. The AST assessment report included results form engine emissions characterizations, near filed interactions, and operational scenarios were applied to global climate models and validated with laboratory studies and atmospheric observations. This report is a "current state of scientific knowledge" assessment of the impact of aircraft on the global environment.

Reduced Seat Cost

Airframe Materials and Structures: Conduct semispan wing test. Plan: September 1999 Actual: July 1999	Testing of the semispan advanced composite wing was conducted and verified the achievement of the weight (25 percent reduction) goal. In addition, seven wing cover panels were fabricated with the resulting verification of the achievement of the cost (20 percent reduction) goal.
Engine Systems: Demonstrate improved turbomachinery design. Plan: September 1999 Actual: September 1999	The Average Passage NASA (APNASA) code was validated for turbomachinery. Design and development cycle time improvements have been demonstrated.
Systems Evaluation: Release final ASAC. Plan: September 1999 Actual: September 1999	The final functionally validated Web-based aviation analysis system with integrated model architecture and advanced system models and databases was delivered and is capable of providing an assessment of potential technology benefits.

Airframe Methods: Three-dimensional high-lift analysis methods validated. Plan: September 1999 Actual: September 1999	Calibrated three-dimensional Navier-Stokes methodology that allows for the analysis of subsonic transport configurations including simulation of the propulsion system power effects was developed and validated.

General Aviation

Complete market assessments. Plan: March 1999 Actual: March 1999	Market assessments of current and latent market for advanced general aviation aircraft have been completed and domestic and international benefits assessed.

ACCOMPLISHMENTS AND PLANS

In **Environment**, an improved and updated community noise impact model to include noise impact minimized flight tracks were completed and released. Full-scale, static engine demonstrations of advanced engine and nacelle noise reduction concepts were conducted. Broadband engine fan noise was investigated in a model-scale, wind tunnel experiment. Sector and full annular testing of low emission combustor concepts were conducted which will meet the 50-percent NOx reduction goal for large engines. . A report was published was based on the "current state of scientific knowledge" assessment of the impact of subsonic aircraft on the global environment.

In **Reduced Seat Cost**, improved turbomachinery design codes were applied and validated to demonstrate increased capability (highly efficient, environmentally compatible and reliable) engine systems. Testing of the semispan advanced composite wing was conducted and verified the achievement of the weight (25 percent reduction) goals, and wing cover panels were fabricated with the resulting verification of the achievement of the cost (20 percent reduction) goal. An analysis method for an integrated aerodynamic design of the wing with the propulsion system was validated and provided to industry to contribute to a reduced design cycle time. Following completion of evaluations of the earlier release, the operational version of the ASAC computer code, including aviation databases and economic and aviation system analysis models, was released to complete the Systems Evaluation project.

In **General Aviation**, work was completed in ice protection and propulsion sensors and controls. The assessments of current and latent general aviation markets will be conducted. The AGATE "highway-in-the-sky" operating capability began final development, with the planned certification issues resolution for COTS-based avionics and display hardware and software architecture for the cockpit being addressed as part of the Vehicle Systems R&T Base Program. Flight training learning modules were developed for next generation AGATE cockpit systems.

BASIS OF FY 2001FUNDING REQUIREMENT

AVIATION SYSTEMS CAPACITY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Aviation Systems Capacity	53,888	62,929	59,200

PROGRAM GOALS

According to airline representatives, delays in the Air Traffic Control System cost U. S. operators approximately $3.5 billion per year in excess fuel burned and additional operational costs. The number of airports experiencing 20,000 hours of delay each year is projected to increase by 50 percent by 2003. Due to environmental issues and cost, only one major new U. S. airport—in Denver—was opened in the 1990's. With little ability to build new or expand current airports in the populated areas where they are needed, airport delays will continue to grow. More efficient and flexible routing, scheduling, and sequencing of aircraft in all weather conditions is critical to meeting capacity demands. The U. S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap still exists between the industry's desired capacity and the ability of the National Airspace System to handle the increased air traffic. Another part of the solution to capacity demands is to off-load the major airports by developing short-haul routes among the 5200 public-use airports available throughout the country. Studies conducted by Boeing Commercial Aircraft, for NASA and the FAA, and by various state and local transportation authorities (e.g., Ports of New York and New Jersey Authority) have shown the civil tiltrotor to be a viable candidate for relief of air traffic congestion.

The ASC program supports on the Enterprise's Global Civil Aviation goal of "tripling the aviation system throughput in all weather conditions, by 2007, while maintaining safety". The goal of the Aviation System Capacity (ASC) program is to enable safe increases in the capacity of major US and International Airports through both modernization and improvements in the Air Traffic Management System and the introduction of new vehicle classes which can potentially reduce congestion, specifically: to increase National Airspace System (NAS) throughput while assuring no degradation to safety or the environment; to increase the flexibility and efficiency of operations within the NAS for all users of aircraft, airports and airspace; and to reduce system inefficiencies.

STRATEGY FOR ACHIEVING GOALS

The ASC program is composed of the Terminal Area Productivity (TAP), Advanced Air Transportation Technologies (AATT), and the Civil Tiltrotor (CTR) projects. The TAP project develops technology and procedures to support the aviation systems infrastructure by reducing system delays and enabling new modes of airport operation to support "Free Flight." The AATT project develops decision making technologies and procedures to provide all airspace users with more flexibility and efficiency, as well as enable new modes of operation that support the FAA commitment to "Free Flight." The CTR project develops technologies and procedures to overcome

inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The ASC program works closely with manufacturers, the airlines and the FAA, who are responsible for applying the candidate technologies as operational systems.

In the area of Air Traffic Management R&D, NASA and the FAA have an integrated research and technology development plan, approved by both the NASA Associate Administrator for Aero-Space Technology and the FAA Associate Administrator for Research and Acquisition. An Inter-Agency Integrated Product Team (IAIPT) is responsible for the strategic management of this area of research by the FAA and NASA, assuring that the efforts of both agencies are conducted to maximize the benefits of the research. The IAIPT reports to a NASA/FAA Executive Council, comprised of the appropriate Associate Administrators from both Agencies. Each agency is responsible for the conduct of its Programs. Oversight of the NASA Programs is provided through the NASA Advisory Council. The Ames Research Center is the lead center for the program and each of the three current projects, with the Langley and Glenn Research Centers providing supporting research.

The Terminal Area Productivity (TAP) project is focused on increasing capacity at airports. The objective is to provide technologies and operating procedures enabling productivity of the airport terminal area in instrument-weather conditions to safely match that in clear-weather or visual conditions. In cooperation with the FAA, NASA's approach in TAP is to develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management (ATM) and reduce controller workload, improve low-visibility landing and surface operations, and to integrate aircraft and air traffic systems to address the problems described above. By the end of the decade, integrated ground and airborne technology will safely reduce spacing inefficiencies associated with single runway operations as well as the required spacing for independent, multiple runway operations conducted under instrument flight rules. Single runway operations are expected to increase by at least 12 to 15 percent under instrument weather conditions. Given the capabilities of future air traffic control automation and improved wake vortex knowledge, "dynamic spacing" between pairs of aircraft types in the landing sequence for an airport runway system is possible and desirable for maximum safety, capacity and efficiency.

The goal of the Advanced Air Transportation Technologies (AATT) project is developing technologies to enable the next generation of increases in capacity, flexibility and efficiency, while maintaining safety and not degrading the environment, of aircraft operations within the U. S. and global aviation system. In alignment with the national consensus for the operating paradigm of the future, called "free flight", the technical objective is to provide human-centered, error-tolerant automation to assist in short- and intermediate-term decision-making among pilots, controllers and dispatchers to integrate block-to-block planning services. This will allow all airspace users to choose the best flight path for their own purposes within the constraints of safety and the needs of other users. Specific objectives include: (1) enabling "free flight" to the maximum possible degree to allow users to maximize business/customer impacts by making trade-offs between time and routing; (2) improving the effectiveness of high-density operations in regions on the ground and in the air where free flight will not be possible, and (3) enabling operation in a smooth and efficient manner across boundaries of free flight and capacity-constrained flight regions.

While the tiltrotor has been shown to be a viable military aircraft (V-22 Osprey), insufficient research has been undertaken on technologies critical to civil applications such as noise, terminal area operations, safety, passenger acceptance, weight reduction, and reliability. The Civil Tiltrotor (CTR) project focuses on noise reduction; cockpit technology for safe, efficient terminal area operations; and contingency power. To achieve acceptable levels of external noise in the terminal area, prop-rotor noise must be

reduced by six decibels A-weighted (dBA) over current technology. Complex flight profiles involving steep approach angles and multi-segmented approach paths will be developed to provide an additional six dBA reduction. To enable these approaches to be safely flown under all weather conditions, integrated and automated control laws and displays will be developed.

SCHEDULE AND OUTPUTS

Terminal Area Productivity:

Demonstrate Advanced Vortex Sensing System with transport of vortices and class-wise spacing Plan: September 1999 Actual: September 1999	Conducted demonstration of AVOSS technologies with transport of vortices and class-wise spacing features including performance of vortex transport models for use by FAA to potentially reduce approach spacing standards.
Conduct simulation of full CTAS coordinated with FMS Plan: April 2000 Revised: July 2000	Conduct full-mission simulation of Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS) decision support tools operating in coordination with aircraft Flight Management System.
Complete demonstrations of all TAP-developed technologies and procedures Plan: September 2000	Complete all of the demonstrations for the TAP project. Demonstrate all TAP technologies in a realistic NAS environments achieving a 12 – 15 % increase in single runway throughput and proving the ability to space aircraft closer than 3,400 feet on parallel runways while meeting all FAA safety criteria.

Advanced Air Transportation Technologies:

Complete definition of expanded operational evaluation of advanced air transportation technologies for: application to complex airspace distributed air/ground traffic separation Plan: September 1999 Actual: September 1999	Completed studies and down-selected recommended approaches to expanded operational evaluation for complex airspace and distributed air/ground traffic separation.
Develop, demonstrate and transfer extended terminal area decision support tools for arrival and surface operations in support of the FAA Free Flight Phase 1 Program Plan: September 2000 Revised: June 2000	Conduct field evaluations of individual decision support tools for management of arrival and surface traffic. Transfer technology to the FAA Free Flight Phase 1 Program.
Develop and demonstrate transition airspace decision support tools for: ATC/airline operations center and ATC/cockpit information exchange Conflict resolution. Plan: September 2001	Develop and demonstrate transition airspace decision support tools. These tools will enable information exchange between ATC/airline operations centers and ATC/cockpits for collaborative decision-making. These tools will also enable prediction of aircraft conflicts both by ATC and flight crews.
AATT Product validation complete Plan: September 2004	Complete validation and assessment of NASA-developed advanced air transportation technology products that will result in a 30 % increase terminal area throughput.

Civil Tiltrotor:

Flight database of low-noise operating procedures Plan: July 1999 Actual: October 1999	Acquired an in-flight database for low-noise operating procedures. Obtained repeatable data points for the following approaches: 6 degree baseline, 3 degree straight, and two low noise profiles – double segmented, first a 3 degree, then a 9 degree. The low noise flight profiles were 7 dB less than the baseline – this met the program element goal.
Isolated Rotor database for low-noise rotor concepts and initial noise code (TRAC) Plan: December 1999 Actual: December 1999	Acquired rotor database for low-noise rotor concepts and for code validation.
Full-span database for low-noise rotor concepts and final noise code (TRAC). Plan: January 2000 Revised: March 2000	Complete full-span wind-tunnel testing of civil tiltrotor model to demonstrate low noise rotor concepts and acoustic code validation with wake and fuselage effects. Test delayed due to unavailability of wind tunnel because of technical problems
Comprehensive mission simulation database of integrated cockpit and operating procedures for complex, low noise flight paths Plan: September 2001	Conduct mission simulations to develop a comprehensive database for complex, low noise flight paths of a civil tilt-rotor with integrated cockpit and operating procedures. The simulations will integrate noise data, operating procedures and cockpit systems evaluated in earlier simulation and flight experiments.
Large scale database for validation of rotor noise reduction and validated design for noise capability (TRAC). Plan: September 2001	Acquire a large-scale database for validation of rotor noise reduction and validated design-for-noise capability.

ACCOMPLISHMENTS AND PLANS

During FY 1999, in the **Advanced Air Transportation Technologies** project, the definition of an expanded operational evaluation of advanced air transportation technologies for application to complex airspace and for distributing tasks between flight crews and ground controllers for safe air to air separation was completed. The **Terminal Area Productivity** project, conducted a demonstration of AVOSS technologies with transport of vortices and class-wise spacing features including performance of vortex transport models for use by FAA to potentially reduce approach spacing standards; and conducted a flight demonstration of the

airborne information for lateral spacing (AILS) concept to enable independent approaches to parallel runways spaced 2500 feet apart. In the **Civil Tiltrotor** project, wind-tunnel testing of isolated rotor models acquired a database for five low noise rotor concepts. Using higher harmonic control, the principal annoying impulsive noise during approach, due to blade-vortex interaction, was virtually eliminated, resulting in 13.5 dB noise reduction. This exceeded the program element goal of 6 dB reduction. An in-flight database for low-noise operating procedures was also obtained. Compared to the baseline 3 and 6 degree approaches, two low noise profiles – double segmented (first a 3 degree, then a 9 degree) were 7 dB less than the baseline. This exceeded the program element goal of 6 dB for low noise flight approaches. The low noise flight profiles were first predicted by a computer model and then verified by the flight noise measurements on the XV-15 Research Aircraft. These flight tests were supported by simulation work conducted in the Vertical Motion Simulator, to assure Level 1 handling qualities.

During FY 2000, in the **Advanced Air Transportation Technologies** project, field evaluations will be conducted to evaluate and demonstrate individual decision support tools for management of arrival- and surface operations in support of the FAA Free Flight Phase 1 Program. The **Terminal Area Productivity** project will be completed in FY 2000 with final demonstrations of all developed technologies and procedures. Program expected to demonstrate potential for an increase of 12 to 15% in airport throughput. Specifically, full-mission simulations will be conducted to demonstrate CTAS on the ground integrated with airborne FMS in the flight vehicles utilizing data-link capabilities to facilitate information exchange between CTAS FMS, and a demonstration of the AILS operational concept to closely spaced parallel runways interacting with other air traffic. In addition, a demonstration of all completed AVOSS technologies for use by FAA to potentially reduce approach spacing standards. In the **Civil Tiltrotor** project, wind -tunnel testing of a full-span tilt-rotor model will demonstrate low-noise rotor concepts and will validate acoustic codes with wake and fuselage effects.

During FY 2001, in the **Advanced Air Transportation Technologies** project, field evaluations will be conducted to demonstrate transition airspace decision support tools in support of 1) information exchange between air traffic service providers, airline operations centers, and flight crews, 2) conflict resolution. The decision support tools with information exchange will enable collaborative decision-making between ATC and the aircraft operators to optimize both ATC and airline operations. Conflict detection capabilities by both the ATC and aircraft will enable optimization of both overall traffic flow as well as individual aircraft flight trajectories. The **Civil Tiltrotor** project will acquire a comprehensive mission simulation database of integrated cockpit and operating procedures for complex, low noise flight paths of a civil tiltrotor. Also, a large-scale database will enable validation of both rotor noise reduction and a design-for-noise capability. The Tiltrotor Aeroacoustic Code computer program will enable the predictive capability.

BASIS OF FY 2001 FUNDING REQUIREMENT

AVIATION SAFETY PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Aviation Safety Program	---	64,394	70,000

PROGRAM GOALS

The world-wide commercial aviation major accident rate has been nearly constant over the past two decades. While the rate is very low (approximately one hull loss per 2 million departures), increasing traffic over the years has resulted in the absolute number of accidents also increasing. The world-wide demand for air travel is expected to increase even further over the coming two decades - more than doubling by 2017. Without an improvement in the accident rate, such a traffic volume would lead to 50 or more major accidents a year — a nearly weekly occurrence. Given the very visible, damaging, and tragic effects of even a single major accident, even approaching this number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system, and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. The GA market may grow significantly in future years, and safety considerations must be removed as a barrier if this growth is also to be realized. Controlled Flight into Terrain (CFIT) and loss of control are the two largest commercial accident types, with weather, approach and landing, and on-board fire as additional significant categories. Human error is cited above all other issues as the prime contributing factor. For General Aviation, weather issues, CFIT, and loss of control also dominate the accident statistics.

In February 1997, to aggressively address these issues, President Clinton announced a national goal to reduce the fatal accident rate for aviation by 80% within ten years. This national aviation safety goal is an ambitious and clear challenge to the aviation community. NASA responded to the President's challenge with an immediate major program planning effort to define the appropriate research to be conducted by the Agency. Four industry- and government-wide workshops were conducted in early 1997 to define research needs. Four hundred persons from over one hundred industry, government, and academic organizations actively participated in setting the research investment strategies. This led to NASA's aviation safety initiative and a redirection of the Aeronautics Research and Technology Base in FY 1998 to immediately begin aviation safety research. The Aviation Safety Program (AvSP) is NASA's next step in responding to the challenge. The goal of AvSP is to develop and demonstrate technologies that contribute to a reduction in aviation accident and fatality rates by a factor of five by the year 2007 compared to the 1994-1996 average.

STRATEGY FOR ACHIEVING GOALS

The NASA AvSP approach for contributing to the national goal is to develop and demonstrate technologies and strategies to improve aviation safety by reducing both aircraft accident and fatality rates. Program planning gives high priority to those strategies that address factors determined to be the largest contributors to accident and fatality rates as well as those that address multiple classes of factors. Research and technology development will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The safety program will emphasize not only accident rate reduction, but also a decrease in injuries and fatalities when accidents do occur. The program will also develop and integrate information technologies needed to build a safer aviation system--to support pilots and air traffic controllers--as well as provide information to assess situations and trends that might indicate unsafe conditions before they lead to accidents. The focus of each program element is the development of one or more prevention, intervention, or mitigation strategies aimed at one or more causal, contributory, or circumstantial factors associated with aviation accidents.

The AvSP will work as partners with the Federal Aviation Administration (FAA) in implementing the program and will maintain close coordination with the Department of Defense and other government agencies. Additionally, the program will work in concert with the full spectrum of commercial, rotorcraft, and general aviation industry manufacturers, suppliers, and operators in implementing the effort. Langley Research Center (LaRC) is the program's Lead Center and works closely with program personnel at Ames (ARC), Glenn (GRC), and Dryden (DFRC) Research Centers.

The AvSP programmatic and technical approach has been developed in close cooperation with the FAA as well as the broad aviation community. The Aviation Safety Program Manager is a member of the Commercial Aviation Safety Team and the General Aviation Joint Steering Committee, the government/industry leadership groups developing and managing the overall National safety strategies. NASA aviation safety research and development efforts will therefore complement both FAA and industry activities as a coordinated overall effort.

Based on the AvSP goal, the criteria for program mission success is to develop technologies that, when implemented by the aviation community, will contribute to a reduction of the civil aviation rate. The program mission success criteria are to produce:

- Human-error assessment methodologies that allow system designs and procedures to be analyzed for error susceptibility – validated in piloted simulation

- Health and Usage Monitoring technologies that enable real time and trending status of critical on-board aircraft systems – demonstrated in flight

- Affordable technologies and systems for the data-linked communication and on-board graphical display of critical aviation weather information both nationally and internationally – demonstrated in flight

- Turbulence modeling and detection technologies that allow for predictive warning and/or avoidance of severe turbulence encounters - demonstrated in flight

- Synthetic Vision technologies and feasible, demonstrated system concepts that provide immediate clear day-equivalent visual awareness and avoidance of world-wide terrain and obstacles in any weather or light condition – demonstrated in flight

- Precision approach and landing technologies and displays that provide intuitive guidance and piloting decision support worldwide, at any runway, at any airport, for both general and commercial aviation – demonstrated in flight

- Advanced structural and material designs that demonstrate 20-40% improvement in crash survivability and fire hazard mitigation – demonstrated in simulation

- Integrated aviation system monitoring tools and infrastructure design operational for at least two major airlines and accessible both nationally and internationally, allowing regular operational assessments to identify unsafe trends before they become accidents

Associated with each technology development effort will be on-going activities by NASA and the FAA to motivate and assist in the implementation of program outputs into the aviation community. NASA researchers will stay involved to help program "outputs" become "outcomes." This process will mean that NASA will work with industry and FAA partners to progress technologies through implementation. This process will be assessed through an Implementation Readiness Level (IRL) scale complementing the TRL scale noted above.

The Technical Program is comprised of six major projects:

Aviation System Monitoring and Modeling (ASMM) projects provide decision-makers in air carriers, air traffic management, and other air services providers with unprecedented in-depth measures of the health, performance, and safety of the National Aviation System (NAS).

The three-fold approach of ASMM is to (1) develop advanced information technology linkages, data structures, and tools to readily access information pertaining to all aspects of the NAS operation; (2) develop tools to identify, analyze and characterize both normal and non-normal operations and uncover previously unrecognized situations that may indicate changes to levels of safety; and, (3) provide world-wide capabilities to obtain, access, and share relevant data on aviation operations among the aviation community.

System-Wide Accident Prevention (SWAP will purse research activities in three key areas identified from in-depth assessments as the highest priority applications: (1) Human Error Modeling, (2) Training, and (3) Maintenance Human Factors. Human Error Modeling efforts will target key aviation hazard issues (such as flight deck automation hazards, controlled flight into terrain, and others) to develop, test, and prove general design principles and operational improvements from a human-centered perspective. Training research efforts will target both training effectiveness improvements (training to performance levels over training to pass a

test) as well specific training module developments for key safety issues such as flying in icing conditions. Maintenance Human Factors will make key investments in developing applications for procedural improvements and will as technologies for advanced displays and automation.

Single Aircraft Accident Prevention (SAAP) will pursue research activities in the following technology areas: (1) Health Management and Flight Critical Design Technologies, and (2) Control Upset Management. Health Management and Flight Critical Design technology developments will utilize advanced on-board measurement and diagnostic methodologies to monitor key flight systems for both hard failures and previously unrecognized trends leading to failures. Significant safety improvements and maintenance cost savings are expected. Control Upset Management technologies will target automated and pilot control techniques to prevent aircraft upsets resulting from systems failures or external inputs as well as techniques for recovering from unusual attitude conditions should an unavoidable upset occur.

Weather Accident Prevention (WxAP) projects will develop and support the implementation of technologies to reduce the fatal accident rate induced by weather hazards. All aircraft types are to be considered. WxAP will pursue research activities in the following technology areas: (1) Aviation Weather Information Dissemination and Presentation and (2) Turbulence Detection and Mitigation.

By developing precision navigation applications, advanced weather- penetrating sensors, high resolution terrain data bases, and graphical cockpit displays, **Synthetic Vision** technology development will provide commercial and general aviation pilots with clear out-the-window views regardless of the actual visibility conditions. In addition to the potentially very large safety improvements, which would result from such a revolutionary system, substantial operational benefits should also result from added all-weather aircraft capabilities.

The Synthetic Vision project will focus on technologies and system applications of terrain displays, enhanced visions systems, precision approach and landing guidance and displays, and low visibility surface operations.

Accident Mitigation (AM) projects will develop, enable, and promote the implementation of technology to increase the human survival rate in survivable accidents, and to prevent in-flight fires. The overall approach in AM is to reduce the physical crash dynamics hazards, minimize fire effects in order to allow more time for evacuation, and reliably detect/suppress in-flight fires. AM technologies are targeted at all classes of aircraft.

SCHEDULE AND OUTPUTS

Preliminary integrated program assessment Plan: January 2000	Complete a preliminary safety impact assessment of the AvSP integrated program.
Apply Aircraft Performance Monitoring System (APMS) to Air Traffic Control (ATC) Plan: June 2000 Revised: March 2000	Demonstrate application of APMS concepts & methodologies to ATC for performance monitoring
CD-ROM Icing Training Module Plan: September 2000 Revised: December 1999	Developed CD-ROM icing training module for General Aviation and commuter pilots.
Simulation Database for Adverse Conditions and Loss of Control Plan: September 2000	Complete development of a preliminary simulation database, mathematical models and 6 degree-of-freedom vehicle simulations to characterize adverse conditions, failures, and loss of control
Initial Aviation Weather Information Network (AWIN) Concept Flight Evaluation Plan: September 2000	Flight Evaluation of initial national capability for digital data link and graphical display of weather information.
Flight Demonstration of Runway Incursion Prevention Technologies Plan: September 2000	Concept demonstration of integration of air traffic control runway incursion information onto aircraft flight deck displays.
Flight Crew knowledge standards Plan: December 2000	Complete the development of flight crew knowledge and proficiency standards for automation.
Tools for causal and risk assessment Plan: September 2001	Demonstrate in an operational environment, tools for merging heterogeneous databases to aid causal and risk assessment.

Onboard health management system Plan: September 2001	Define an architecture for an integrated onboard health management system
SV retrofit concepts Plan: September 2001	Evaluation of concepts in simulations and flight tests utilizing situational awareness measurement tools developed for the analysis of SV retrofit concepts.
Reduce fuel system flammability Plan: September 2001	Successfully complete the experimental and analytic laboratory environment demonstration of fuel system modifications to reduce flammability.
Advanced Fire detection systems Plan: September 2001	Complete the design criteria for low false-alarm fire detection systems.
Safety Improvement Concepts developed Plan: September 2001	Conceptual designs of safety-improvement systems are completed for all projects in September 2001. .
Interim Integrated Program Assessment Plan: June 2002	Interim assessment impact assessment of AvSP integrated program completed. Projected impact on accident rates for research projects completed and provided in a summary report
Simulations and Flight Test Evaluations of Safety-Improvement Systems within AvSP Completed Plan: March 2003	Individual safety-improvement systems have been evaluated in simulators and flight tests:
Integrated Full-Mission Applications, Simulations, and Flight Demonstrations Plan: June 2004	Mission-capable safety-improvement systems have been integrated into full system and demonstrated in flight:
Final Integrated Program Assessment Plan: September 2004	Final Safety impact assessment of AvSP integrated program completed: - Projected impact on accident rates for research projects completed and provided in a summary report

ACCOMPLISHMENTS AND PLANS

In FY 2000 the first year of the program, the Weather Accident Prevention project will complete flight evaluation of an initial national capability for digital data link and graphical display weather information in an aircraft cockpit. This will be an assessment of cockpit "weather channel" concept for national and worldwide commercial airline and general aviation benefit. Selections of concepts for continued development will be conducted for clear air turbulence detection systems. The System-Wide Accident Prevention project will develop and demonstrate an icing training module on CD-ROM for general aviation and commuter pilots. This will enable the board dissemination of critical weather safety information to the national aviation community. Software application field tests will begin for maintenance human factors risk database, mathematical models, and six degree-of-freedom vehicle simulations to characterize adverse conditions, system failures and loss of control mitigation techniques. Synthetic Vision flight demonstration tests of FAA and NASA runway incursion technologies integrated onto an aircraft flight deck will be conducted at a major U.S. airport. These tests will provide technical and operational warning systems into current technology cockpits. The Aviation System Monitoring and Modeling project will demonstrate the application of Aircraft Performance Measurement System concepts and methodologies to Air Traffic Control systems for performance monitoring. This work will take successful aircraft-based monitoring technologies and apply them to the broader context of the national airspace system risk identification and performance improvements. Airline evaluations and operational use of aircraft performance measuring software and analysis tools will be conducted. In the Accident Mitigation projects area, on-board inert gas and oxygen generation system concepts for fire prevention and emergency use will be defined and structural crashworthiness design analysis prediction codes development selections will be conducted.

For FY 2001, Aviation System Monitoring and Modeling will demonstrate, and simulate of NASA-wide operation for ground and flight in an operational environment, tools for merging heterogeneous databases to aid causal analysis and risk assessment. The intent is for the primary products to be commercialized. System-Wide Accident Prevention will complete development of flight crew knowledge and proficiency standards for automation and deliver them to industry for evaluation and develop prototype-training materials for evaluating skill-specific maintenance resource management (MRM) intervention. Single Aircraft Accident Prevention will define architecture for integrated onboard health management systems. These designs will provide sufficient criteria to support development of concept prototype to be used for simulation and flight demonstrations. For the National Capability Demonstration, Weather Accident Prevention will develop system end-to-end atmospheric models and sensor simulation for selected hazards and sensor technologies and candidate hazard algorithms. Turbulence Detection will develop a simulation demonstration of turbulent-tolerant flight control algorithm. This simulation of system results in 80% or better detection rate for moderate turbulence within 1 minute of encounter. Accident Mitigation will demonstrate in an experimental and analytic laboratory environment, of a fuel system modification to reduce flammability, and validate system designs in an representative fire environment experiment, showing reliability and low false-alarm characteristics. Synthetic Vision will down-select concepts suitable for retrofit in commercial, business, and general aviation aircraft, and investigate the use of altimeter and weather radars as means for monitoring the integrity of Synthetic Vision Systems databases.

BASIS OF FY 2001 FUNDING REQUIREMENT

ULTRA EFFICIENT ENGINE TECHNOLOGY

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Ultra-efficient engine technology	---	68,306	35,000

PROGRAM GOALS

NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA's role in aeronautics is also to support the Department of Defense (DoD) in maintaining superior air defense capability. Propulsion has led the way for new generations of aircraft with breakthroughs in performance, reliability, and environmental compatibility. A prime example of NASA's contribution to technological advances in propulsion is the high bypass turbofan. This engine enabled the economic success of wide-body transport aircraft and achievement of new levels of fuel efficiency and dramatically reduced noise as compared to the earlier generation of jet aircraft. The attainment of Aero-Space Technology Enterprise goals requires comprehensive propulsion technology research and development spanning a broad range of aircraft applications from subsonic through hypersonic. The timing is right to invest in breakthrough technologies for a new breed of radically improved propulsion systems to power a new generation of aircraft required in the increasingly constrained airspace system.

NASA has a successful history of leading the development of aggressive, high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. The Ultra Efficient Engine Technology Program addresses the most critical propulsion issues facing the Nation in the new millennium: performance and efficiency. In order to sustain the desirable forecasted growth of this important industry, these issues must be addressed without dampening this growth and therefore must improve performance and efficiency without incurring environmental penalties. Additionally, it is important to sustain the high reliability and safe operation without impacting the economics of operations. These propulsion technologies will also be of significant benefit to military engines where performance improvement is the principal goal driving DoD propulsion development for future military aircraft.

STRATEGY FOR ACHIEVING GOALS

The Ultra Efficient Engine Technology Program is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical,

reliable and environmentally compatible U.S. aircraft. The breakthrough technologies are focused on propulsion component and high temperature engine materials development and demonstrations enabling future commercial and military propulsion systems which are greatly simplified, achieve higher performance, and have potential for much reduced environmental impact with a broad range of aircraft applications. Seven investment areas form the basis for the technical approach: materials & structures, to address the barrier technologies and expand the knowledge databases required for future designs of high temperature, long life, high performance propulsion systems; combustion, to develop the technologies necessary to minimize the emissions characteristics of future propulsion systems; turbomachinery, to develop highly coupled/loaded engine component technologies incorporating breakthrough features with potential for integrated propulsion demonstrations; propulsion - airframe integration to develop approaches and technologies for integrating next generation propulsion systems with revolutionary aerospace vehicle designs so as to maintain high levels of installed propulsion system performance; intelligent propulsion system controls to leverage the emerging intelligent systems (IS) technologies to apply to revolutionary propulsion system architectures; integration & assessments, to understand the complexity of interplay among technology benefit, tradeoff and impact; and integrated component technology validations to demonstrate the ability to integrate technologies and achieve revolutionary levels of sub system/system performance.

NASA's investments will develop the underlying understandings and design information to mitigate both the risk and cost of applying the technology-based solutions. The success of this program is dependent on partnerships to enable transfer of the resulting technology. As a result, a key element of this program is to develop high-payoff technologies, in cooperation with DoD, the Federal Aviation Administration (FAA), the Environmental protection Agency (EPA), the U.S. aeronautics industry and academia, to benefit the public.

The Glenn Research Center is the lead center for the UEET Program and five of the seven projects (combustion, materials and structures, turbomachinery, integration and assessment, and integrated component technology validation). Langley Research Center has project management responsibility for the propulsion-airframe integration project and Ames Research Center has project management for the intelligent propulsion system controls project. Goddard Space Flight center provides critically important supporting research in the atmospheric assessment subproject of the integration and assessment project.

SCHEDULE AND OUTPUTS

Combustion: Combustion research facility upgrade completed Plan: September 2000	Complete the development and fabrication of the upgrade to the Combustion Research Facility, a unique world class facility, which is required for testing of combustor configurations (flame tube and sector) required for future ultra high-pressure ratio engine cycles.
Combustion: Select 70% emissions reduction concept for full combustor evaluation Plan: September 2000	Demonstrate in a laboratory combustion experiment (flametube) an advanced turbine-engine combustor concept that will achieve up to a 70% reduction of oxides of nitrogen (NOx) emissions based on 1996 ICAO standard.

Materials & Structures: Complete high temperature engine material down-select Plan: September 2000	Complete selection of those materials systems that will be developed for complex geometries such as cooled turbine vanes with thermal barrier coating and capable of sustained 3100°F turbine rotor inlet temperatures
Turbomachinery: Validation of aero-performance prediction code Plan: September 2000 Actual: Deleted	Complete single stage cascade tests of turbine configurations which incorporate flow control to improve aerodynamic performance and use flow physics data set acquired to validate NASA's average passage (APNASA) computer code. Milestone was developed early in planning of UEET program. Final validation of aero-performance prediction code will occur in FY 2004 (level 1 program milestone).
Integration & Assessment: Complete baseline propulsion system development and technology assessments Plan: September 2000	Complete the development of baseline system configurations and the preliminary assessment of UEET revolutionary candidate technologies
Prediction of propulsion-airframe integration Plan: October 2000	Complete selection of the most promising simulation approach for predicting propulsion-airframe integration effects for unconventional aerospace vehicles.
Flow Control Concepts for advanced propulsion systems Plan: December 2000	Complete selection of the most promising flow control concepts that will be developed for application to the turbine components of advanced propulsion systems.
Definition of advance propulsion options Plan: September 2001	Complete definition of advanced propulsion options incorporating UEET low emissions combustor, high temperature materials and highly loaded turbomachinery candidate technologies.
1350 deg. turbomachinery disk alloy Plan: September 2001	Demonstrate the required materials properties in scaled-up forging for a 1350 deg F turbomachinery disk alloy.
Integration and Assessment: Complete interim assessment of UEET technologies Plan: September 2003	Complete the interim assessment of the projected system impacts of low emissions and improved performance technologies incorporating experimental results and simulation predictions completed to date.

Integration and Assessment: Complete final assessment of UEET technologies Plan: September 2005	Complete the final assessment of the projected system impacts of low emissions and improved performance technologies incorporating the complete suite of experimental results and simulation predictions completed in the UEET Program.

ACCOMPLISHMENTS AND PLANS

Combustion In FY 2000, a world class high pressure ratio combustion research facility upgrade will be completed to allow parallel operation of basic combustion research for combustion diagnostics and physics based model calibration and for flame tube and sector testing to validate advanced high performance combustor designs. This facility allows for realistic testing of combustion concepts applicable for the high pressure ratio engine cycles envisioned which will fully utilize the technologies developed in the UEET program to achieve revolutionary advances in gas turbine engine performance. In FY 2000, flame tube tests will be conducted to identify the most promising approaches for achieving the 70 percent NOx reduction goal. In FY 2001, the results of these flame tube tests will be used to design and fabricate sector configurations of ultra low emissions configurations for subsonic engine applications. Limited model tests will be conducted in government or industry facilities as appropriate to validate the emissions reduction potential. State of the art instrumentation will be used to measure particulate and aerosol characteristics of these advanced combustor configurations. These results will be used in atmospheric impact assessments to be accomplished as part of the Integration and Assessment project.

Materials & Structures: In FY 2000, the selection of those materials systems that will be developed to the subcomponent, complex part scale in this program will be completed. The suite of materials from which this selection will be made is focused only on those critical to enable the high performance 21st Century propulsion systems. An initial high priority activity completed in FY 2000 was the selection of the most promising approaches for developing a low conductivity thermal barrier coating, a critical constituent for a high temperature turbine airfoil material system. One critical material system, Ceramic Matrix Composites (CMC), is essential to both future commercial and military engines. This program is the only national effort in CMC's and is a key technology where DoD is reliant on NASA. CMC work in FY 2000 will be focused on establishing the upper temperature limit of the material developed in the High-Speed Research (HSR) Program. In FY 2001, scaled-up forging will be completed of candidate turbomachinery disk configurations utilizing the 1350 deg F advanced Nickel based material. These forgings will be used to demonstrate that the required materials properties, which have been demonstrated in laboratory scale (i.e. coupon tests), can be maintained when realistic size and configuration subcomponents are fabricated. The optimization of the composition and processing for the turbine blade bond coat will be completed in FY 2001. The bondcoat is another critical constituent of a turbine airfoil material system required for the high-pressure ratio engine cycles envisioned for the 21st century.

Turbomachinery: In FY 2000, flow control concepts will be selected for fan and compressor component applications. A key part of achieving revolutionary turbomachinery performance increases is the use of flow control to allow increased turbomachinery performance in fewer stages. These concept evaluations will be based upon CFD simulations using available computational tools. The most promising approaches will be evaluated through single stage, proof-of-concept tests. In FY 2001, a performance baseline

will be established through low speed wind tunnel testing of a highly loaded, multi-stage fan. This baseline set of results will allow for the design, fabrication, and testing of a more revolutionary highly loaded fan design that will contribute to higher performance, lower weight propulsion system designs. Also in FY 2001, the selection of the flow control concept for the turbine will occur.

Propulsion-Airframe Integration: In FY 2000 a selection will be made of the computational fluid dynamics simulation tool to be used to evaluate the installed performance of the engine concepts being evaluated. In FY 2001, the design and fabrication efforts will be completed for a small-scale active flow control demonstration model. This model will utilize the sensors and actuators, selected during FY 2000 activities. Active flow control technologies show great promise for reducing length and therefore weight of advanced propulsion system inlet designs as well as internal flow passages.

Intelligent Propulsion System Controls: In FY 2000 and FY 2001, initial laboratory experiments are being conducted to assess active combustion control concepts for emissions reduction potential. Systems studies evaluations of payoffs of other intelligent control technologies will be completed. These studies will provide guidance for additional UEET technology development efforts.

Integration & Assessment: In FY 2000, revolutionary propulsion system concepts were defined for both low and high-speed vehicle applications. These propulsion system concepts will incorporate the suite of UEET technologies being developed in the other projects (i.e. ultra low emissions combustor, highly loaded turbomachinery, materials and structures, propulsion airframe integration, and intelligent propulsion system controls) and projections of the revolutionary advances in system and vehicle performance will be made. In FY 2001, a selection will be made of the propulsion system concept for which detailed, multi-disciplinary simulations will be conducted. These simulations will be performed using tools such as those provided by the High Performance Computing and Communications (HPCCP) and Intelligent Synthesis Environment (ISE) Programs.

Integrated Component Technology Validation: In FY 2000, plans were completed for a series of testbed demonstrations incorporating UEET component and materials technologies, which in partnership with the U. S. aeropropulsion industry and / or DoD to accelerate the technology transition to commercial and military customers. In FY 2001, design and fabrication efforts will be completed to allow the testing in FY 2001 - 2002 of the 2200• F CMC combustor liner in an available commercial engine testbed supplied by an industrial partner.

BASIS OF FY 2001 FUNDING REQUIREMENT

SMALL AIR TRANSPORT SYSTEM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Small Air Transport System.....	---	---	9,000

PROGRAM GOALS

Community vitality and economic opportunity depends on access to rapid transportation, in particular air transportation. The new economy, driven by knowledge-based industrial development, will demand ever-safer national transportation system efficiencies. The exponential growth of e-commerce will create demand more speed and timesavings for people, goods and services to more destinations. Airports are magnets for new businesses, new jobs, new community revenues, and new standards of living. Today, the relatively few communities with airports capable of handling turbine-powered aircraft in near all-weather conditions create significant economic benefits compared to communities that are not served by such landing facilities. During the information age as time becomes the "scarce commodity," demand for aviation transportation is expected to outpace capacity provided by the system of about 400 hub-and-spoke airports. Thus, early in the 21st century, when speed is at a premium, the nation's doorstep-to-destination travel speeds will be in decline. The growing delays in the hub-and-spoke system will limit the economic expansion in this information age to well-connected regions and communities. Fortunately, more than 98 percent of the U.S. population lives within a 30-minute drive of over 5,000 public use landing facilities . The safe, efficient utilization of smaller aircraft and smaller, public use airports can provide a revolution in mobility, if the two major technical barriers impeding their use can be overcome: safety of flight and accessibility to these facilities.

Safety of flight. Small aircraft have accident rates more than 10 times that of commuter or large air carriers. A leading causal factor in current general aviation accidents and fatalities is marginal visibility resulting in loss of control or controlled flight into terrain. Plus, today's GA pilot is flying complex operations with antiquated avionics, with far less advanced training, in the worst meteorological conditions, and in the most complex lower-altitude airspace. The enabling technologies can be developed and integrated to bring the safety and mission reliability of single-pilot aircraft to levels equal those of airline operations.

Accessibility. Paradoxically, the Nation's airspace is not crowded; in fact airspace is plentiful. Runways at the large airports are crowded. However, the nation's infrastructure of over 5,000 smaller airports represents an underutilized capacity within the national airspace system. This underutilized capacity appears capable of handing virtually all of the growth that the hub-and-spoke system will not be able to accommodate as saturation occurs. The key inhibitors to the use of these underutilized facilities include the near-all-weather safe operational capabilities of smaller aircraft and the air traffic services infrastructure within this non-towered, non-radar airspace. The enabling technologies can be developed and integrated to give the nation near-all-weather access to virtually every runway end and helipad in the nation.

The challenges to increasing small aircraft contributions to economic development are to create the means in both vehicle and infrastructure technologies to: improve safety by reducing the accident rate of small aircraft to that of commercial transports, utilize the Nation's under-used airspace and landing facilities at non-hub airports in all weather conditions, and increase capacity for efficient operations of general aviation, commuter, regional, and runway independent aircraft near and within hub airport airspace. These SATS technologies will benefit air carriers as well. The deployment of SATS capabilities will: (1) help relieve hub airport and airspace congestion, (2) accelerate the emergence of free flight, and (3) provide air carriers with access to a third tier consumer base in communities too small to be served by existing regional jets.

The goal of the Small Aircraft Transportation System (SATS) program is to address these challenges by enabling a transportation system for safe accessibility to small, underutilized airports through the rapid integration of advanced technologies in next-generation aircraft. SATS vehicle and infrastructure technologies will provide safety levels vastly superior to automobiles and at least as safe as today's commercial air carriers by bringing advanced automation into the cockpit to allow the operator to focus on decision making and reduce training time and cost, and to enable virtual visual flight operations in instrument conditions at non-towered, non-radar landing facilities. SATS provides increased accessibility by more fully utilizing the existing 5,400 public-use facilities. The application of SATS technologies can expand hub-and-spoke capacity by smaller aircraft to use simultaneous non-interfering operations near and within Class B airports and airspace.

STRATEGY FOR ACHIEVING GOALS

The SATS Program will deliver an inter-city transportation system demonstration that integrates SATS vehicle and infrastructure features and capabilities. The SATS Program concept builds on previous lessons learned in public-private partnerships (*e.g.*, from the Advanced General Aviation Transport Experiments (AGATE) Alliance) to structure a Federal-States-Industry SATS Alliance. The essential power of an alliance is to influence those factors that would otherwise be outside the control of any individual member of a partnership. SATS plans to form a national partnership between NASA, the Department of Transportation, FAA, State governments, as well as the Department of Commerce, Industry, and Academia to focus on transportation system engineering, vehicle technologies, and enabling infrastructure technologies. SATS will leverage technologies from both past and current NASA and FAA programs, including NASA Base R&T activities, as well as new industry vehicle programs to implement a compelling demonstration of the SATS innovations.

Two types of demonstrations involving the partnership are the key products of SATS: technology development demonstrations and integrated system demonstration. States will select landing facilities in partnership with the Federal and Local Governments for demonstrations at which localized versions of SATS can be implemented. These demonstrations would validate SATS system technologies and concepts, such as "smart" airport, airborne Internet, simultaneous non-interfering approaches, AutoFlight, and wireless cockpit. These technology activities will support the aircraft, airports, and airspace/procedures design and development required for validation of SATS operating capabilities at small airports. The fidelity and breadth of the integrated system demonstration is planned to produce the full safety and system performance benefits required to enable a decision by industry as well as State and Local governments to accelerate deployment of SATS.

SATS Program products include:

- Simplified automotive-like flight controls and displays and virtual TerPs for "Autoflight"
- Integrated avionics standards and systems for tomorrow's "Wireless Cockpit"
- "Smart Landing Facilities" to provide automation-enabled separation and sequencing in non-towered, non-radar airspace
- Client-server-based architecture for information services on an "Airborne Internet" to support collaborative air traffic management
- "Intermodal Transportation Systems Engineering" coordinated to integrate and coordinate national requirements, technologies, consumer/community response, and program deliverables
- "Public Outreach" for deployment of media and educational information supporting community understanding of SATS

SCHEDULE AND OUTPUTS

Initiate Federal - States Industry SATS Partnerships. Plan: September 2001	Partnership agreement signed by NASA and at least one state government and one industry member.
Initiate Virginia SATS - Lab Partnership. Plan: September 2001	Joint Sponsored Research Agreement with Virginia Space Grant Consortium partners is signed to develop a SATSLab comprised of aircraft, airports, and airspace for validation of SATS vehicle and infrastructure features and capabilities.
Baseline SATS Architecture and Operational requirements Plan: September 2002	SATS Concept of Operations is baselined following review and approval by SATS Alliance partners
Validate 20:1 Runway protection zone HITS approaches. Plan: September 2003	Design standards for establishing a 20:1 runway protection zone for Highway in the Sky (HITS) /Synthetic Vision approaches in near all instrument weather conditions.
Demonstrate "virtual" terminal procedures and autoflight Plan: September 2004	Validate "virtual" TerPs concept in simulation and flight with autoflight capabilities.

Transportation system assessments Plan: September 2005	Complete intermodal transportation system performance and impact simulation.
"Small Aircraft / Small Airport" System Integration Demonstration Plan: September 2005	Demonstrate integration of "virtual VFR" operations, "virtual TerPs," automated "smart" airport traffic operations, and simultaneous non-interfering operations with integrated vehicle systems including intuitive vehicle controls, "plug & play" avionics, and cockpit automation.

ACCOMPLISHMENTS AND PLANS

In support of the milestones identified above, the following activities will be undertaken in FY 2001::

- SATS Concept of Operation drafted including vehicle features and capabilities, intermodal connectivity requirements, systems architecture, technology development needs, and projected economic benefits and costs.
- Initiation of the robust air vehicle and digital airspace technology research.
- Establishment of the partnerships with other agencies and state and local governments in anticipation of showcase technology demonstrations projects integrating SATS products.

BASIS OF FY 2001 FUNDING REQUIREMENT

QUIET AIRCRAFT TECHNOLOGY PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Quiet Aircraft Technology Program	---	---	20,000

PROGRAM GOALS

The goal of the Quiet Aircraft Technology program is to contribute to the 10-year noise objective of the Global Civil Aviation enabling technology goals, as stated in the Office of Aero-Space Technology Enterprise Strategic Plan, "Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within ten years, and by a factor of four within 25 years." The Quiet Aircraft Technology program is the next step in achieving the very ambitious and desirable 25-year goal for the public good. Achievement of the 25-year goal will fulfill NASA's vision of a noise constraint-free air transportation system with the objectionable aircraft noise contained within the airport boundaries. Part of this vision is a transportation system with no need for curfews, noise budgets, or noise abatement procedures. Benefits to the public of achieving these goals include increased quality of life, readily available and affordable air travel, and continued U.S. global leadership.

Until objectionable aircraft noise is contained within airport boundaries through successful implementation of advanced noise reduction technology, noise from subsonic airplanes will continue to be an issue resulting in polices and procedures, like curfews and noise budgets, for noise impact relief. While the results of previous NASA noise reduction research are incorporated in today's aircraft, even more aggressive technology is needed to address, not only the projected growth in operations, but also the public expectation for lower community noise impact.

For over 70 years, NASA with the FAA, industry, academia, and the Department of Defense have cooperatively developed critical aeronautical technologies for the future. Historically, NASA's perspective has been to take the long view and to make high risk, high potential payoff investments. The challenge to NASA is to develop critical technologies while fostering a national vision for aero-space technology development. NASA is unique in its expertise, facilities, and inherent government role to lead the technology development necessary to meet national community noise impact reduction requirements.

Noise impact of subsonic transportation is currently constraining the air transportation system through curfews, noise budgets and limits, and slot restrictions. The number of local noise related restrictions have grown worldwide from 119 airports in 1980, to 354 in 1994, to 595 in 1998. This dramatic growth in local noise-related constraints and the pressure for increased international noise certification stringency is indisputable evidence that the current noise impact status quo is not acceptable to the public. In addition noise issues are critically constraining the growth of the air transportation system by often delaying and sometimes inhibiting the

expansion of needed airport capabilities – such as runway additions, expansions, or new airports. Today's noise-related constraints of the growth of aviation was predicted in the 1995 National Science and Technology Council (NSTC) Report *Goals for a National Partnership in Aeronautics Research and Technology*. The 1999 NSTC report *National Research and Development Plan for Aviation Safety, Security, Efficiency, and Environmental Compatibility* further predicts increasing community noise impact after the phase-out of nosier Stage II airplanes as the number of operations continue to increase. Projections for air travel indicate a tripling of demand for air travel within the next two decades. New noise reduction technology is critically needed to enable this demand-driven increase in air travel. Additional pressure to reduce airplane noise results from cars, trucks, factories, and other sources of community noise becoming quieter. The demand for reduced community noise impact will continue until public expectations are met.

A benefit of achieving the 10-year noise goal is that the 65 Day Night (noise) Level (DNL) will be contained within the airport boundary for the majority of US airports. The significance of this is that this level of noise exposure is deemed so onerous that 65 DNL of noise exposure is a qualifying criteria for the FAA administered home noise insulation program. A benefit of achieving the 25-year noise goal is that the 55 DNL will be contained within most airport boundaries. The EPA has established that noise exposure less than 55 DNL is required to protect "public health and welfare". Containing the 55 DNL within the airport boundary achieves NASA's vision of objectionable airplane noise contained within the airport boundary.

STRATEGY FOR ACHIEVING GOALS

The goal of the Quiet Aircraft Technology program will build upon technology developed in the Advanced Subsonic Technology (AST) Program Noise Reduction Element and in the Base technology development programs to achieve the 10-year Three Pillars noise goal of a factor of two, 10 dB, perceived noise level reduction relative to 1997. Progress in the current planned noise reduction program, the AST and Base programs, is projected to be 5 dB relative to a 1997 baseline. The objective of the Quiet Aircraft Technology program is to develop technology for an additional 5 Effective Perceived Noise Level decibels (5 EPNdB) community noise impact reduction to a Technology Readiness Level (TRL) of 4. This 5 dB consists of both engine and airframe source noise reduction, and advanced operations to reduce community noise impact. Substantial cost sharing with industry would be required to take the developed technology beyond the planned technology readiness level to full-scale noise component reduction concept validation (TRL 6). Achievement of the 10-year National Noise Reduction goal will enable the projected growth in air travel while offering the potential to reduce community noise impact.

Through system analysis the rough order of technical performance required to achieve the required 5 EPNdB additional airplane system noise reduction beyond the AST Noise Reduction Program is 4 dB fan noise reduction, 4 dB jet noise reduction, 1 dB core noise reduction, 4 dB airframe system noise reduction, and validation of the 2 dB operational noise benefit identified in the AST Noise Reduction Program. Technologies which will be pursued to achieve these technical objectives include: computational aeroacoustics, active noise control, inflow distortion management, smart materials, embedded sensors, morphing/smart structures, multidisciplinary component optimization, micro-blowing, adaptive liners, propulsion airframe integration, airplane system optimization, unsteady flow/turbulence control, real-time minimal noise operations, and accurate single event prediction under realistic weather conditions.

SCHEDULE AND OUTPUTS

Demonstrate technologies to reduce community noise impact Plan: September 2000	Demonstrate separate flow jet noise reduction nozzles in flight Demonstrate advanced flight operations to reduce community noise impact Demonstrate advanced active control for GA interior noise
Discovery and initial assessment of concepts to achieve 3 dB airplane system noise reduction Plan: September 2001	Initial assessment of concepts to reduce airframe system noise 4 dB Initial assessment of concepts to reduce engine system noise 4 dB
Select Concepts to reduce airplane system noise and additional 3 db Plan: September 2002	Complete improved future airframe and engine system noise prediction models Select concepts to reduce airframe and engine system noise an additional 4 dB Identified an integrated airborne/ground system implement advanced low noise operations

ACCOMPLISHMENTS AND PLANS

In FY 1999 a suite of engine system noise prediction tools were completed. These predictive tools include source noise prediction models for engine fan tone and broadband noise, jet noise, and core noise. In addition, codes were developed to propagate the source noise predictions through the engine nacelles, including the effects of absorptive liners. These codes are based on fundamental physics, as much as possible, and not only are they used to discover and optimize new engine noise reduction concepts, these predictive codes form the basis to extend validated noise reduction concepts to applications not even envisioned today. In a flight test of a Beech 1900 a practical structural/ acoustic optimized active noise control concept was demonstrated to reduce propeller tone noise by over 10 dB. A community noise impact model referred to as the AirCraft Noise Impact Model (ACNIM) has been developed which incorporates airport noise prediction, census data, and satellite imagery, into a user friendly Geographical Information System (GIS) computer program. The airport noise prediction is performed using the FAA's Integrated Noise Model, which is the standard airport noise prediction tool used around the world. Incorporation of census data, which includes population data and population characteristics, allows the prediction of community impact. Satellite imagery is used in combination with the census data to determine more accurate land use and population locations. ACNIM also incorporates the capability to determine optimized aircraft ground tracks for minimal community noise impact. Results of studies with the developed models indicate that improved high-lift systems, in combination with advanced operational procedures have potential to reduce community impact by the equivalent of a 2-4 dB source noise reduction.

Plans in FY 2000 include the completion of a series of static engine tests to demonstrate engine system noise reduction including both source noise reduction and advanced nacelle concepts. A flight demonstration of a jet noise reducing advanced engine exhaust nozzle will be conducted. Advanced flight operations to reduce community noise impact will also be demonstrated in a flight test program. An improved airframe noise prediction code will be completed. An innovative high lift concept which promises to have low noise and high aerodynamic performance will be tested at model scale in a pressure wind tunnel. A structural/acoustic optimized

passive/active noise control system will be flight tested in a General Aviation airplane. A series of system studies will be conducted to assess component noise reduction concepts required to meet the Enterprise 10-year, 10 dB noise impact reduction goal. In conjunction with the system studies an assessment will be made of the developed noise reduction technologies todate. This assessment will involve projecting model scale results to full-scale applications.

Plans in FY 2001 include the verification of technologies to reduce airframe noise 4 dB on a 26% model of a Being 777. An active noise control system for fan tones will be demonstrated in a static engine test. An initial landing gear airframe noise prediction model will be developed. Jet noise reducing engine exhaust nozzles and modeling of jet noise will be further developed. Results of the detailed system studies performed in FY00 will be used to investigate and initially define identified noise reduction concepts to achieve the 10-year community noise impact reduction goal.

BASIS OF FY 2001 FUNDING REQUIREMENT

2nd Generation RLV

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Systems Engineering & Requirements Definition	---	---	50,000
RLV Competition & Risk Reduction	---	---	95,000
NASA-Unique Systems	---	---	50,000
Alternative Access	---	---	40,000
X-33	277,299	111,600	---
X-34	35,500	40,500	17,900
Future X/Pathfinder	36,000	31,300	37,100
Bantam	16,500	---	---
Total	365,299	183,400	290,000

PROGRAM GOALS

Low-cost space transportation remains the key enabler of a more aggressive civil space program. A central tenant of the National Space Policy is the transition of routine space activities to the private sector to concentrate NASA resources on high-leverage science research, technology development, and exploration activities. By 2005, NASA will conduct a competitive launch services procurement to support the launch requirements of both robotic and human spaceflight operations. The objective will be to dramatically improve safety while significantly reducing the cost of such launch services, thus eliminating the current need for the Government to own and operate a full system.

The 2nd Generation RLV program will substantially reduce the technical, programmatic and business risks associated with developing a safe, reliable and affordable 2nd Generation RLV architecture. The program will invest in the technology development, business planning, design and advanced development efforts to enable at least two competitive options for a new architecture. The program will be implemented to assure that the full-scale development of any new systems can be initiated no later than 2005.

STRATEGY FOR ACHIEVING GOALS

The 2nd Generation RLV FY 2001-2005 program will be divided into four major investments areas: Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction, NASA Unique Systems and Alternative Access.

The Systems Engineering and Requirements Definition effort is critical to establishing the program direction and determining NASA recommendations for appropriate plans and budgets for systems that meet NASA unique requirements on commercial systems. This activity will combine industry and government capabilities to develop detailed technical and programmatic requirements necessary to link technology and other risk reduction efforts to competing architectures. This effort will place a priority on industry and NASA systems engineering activities that seek compatible architectural solutions between commercial industry and NASA requirements. Of paramount importance is achieving significant improvements in safety, reliability and affordability. Improved reliability and affordability can only be achieved through rigorous systems engineering that encourages a distillation of NASA requirements to be compatible with commercial capabilities.

The RLV Competition and Risk Reduction component is designed to allow the U.S. space launch industry to pursue significant technical and economic improvements. These advances must sufficiently reduce the risk in order to enable a competition by 2005 which includes a significant private sector commitment for RLV system development. NASA will pursue risk reduction efforts that will enable at least two competing architectures. The investment in 2nd Generation RLV risk reduction will be driven by the collective efforts of industry and the government and will be based on the direction of competing industry concepts per the precedents set in the X-33, X-34 and X-37 programs. The risk reduction activities will include business development and planning, technology investments, advanced development activities and flight demonstrations or experiments. Planning calls for multiple industry awards with sufficient government insight to assure success. Government partnerships will be established to obviate redundant proprietary development paths and maximize government investment. The selection of industry and NASA investments will be defined consistent with the results of the Systems Engineering and Requirements Definition activities and will be demonstrated (e.g., ground, flight, scale) in the most efficient and cost effective manner.

The third program element is concentrated on developing and demonstrating the designs, technologies and systems level integration issues associated with government unique transportation elements and systems. This will address the additional systems (e.g. crew transport vehicle, cargo carriers, rendezvous and docking systems) necessary to meet unique government mission requirements (e.g. crew transport, cargo return, emergency rescue and return, on-orbit service) using commercial launch vehicles. The content of this program element will be defined through the systems engineering and requirements definition process and will be concurrent with the RLV Competition and Risk Reduction activities. The affordability of an operational architecture to NASA and its compatibility with the commercial launch market will hinge on NASA's final requirements. NASA intends to explore innovative approaches with broad trade studies and a wide variety of systems solutions to efficiently address NASA-unique requirements. NASA will seek the development of unique assets that could be operated in conjunction with multiple commercially provided RLV assets. This program element will consist of contracted efforts in combination with government design, development and integration activities. Solicitations for industry involvement will be conducted in parallel with the RLV Competition and Risk Reduction solicitations. Crew Return Vehicle (CRV) Phase II outyear funding has been transferred to this program element, pending future decisions on whether to pursue a CRV separate from other systems to meet NASA-unique mission requirements on commercial launch vehicles.

The fourth program element, Alternative Access, seeks to take advantage of all potential sources of access to space on U.S. launch systems to meet the Agency's requirements. This element supports use of existing and emergent commercial launch vehicles that could launch NASA science payloads and potentially service Space Station requirements. NASA will use the Next Generation

Launch Services (NGLS) acquisition as a means to develop contractual relationships with multiple emerging U.S. vendors to meet this objective. These contracts will be for fixed-price services for indefinite delivery indefinite quantity launch contracts.

SCHEDULE AND OUTPUTS

Receive Industry Proposals Plan: October 2000	Receive Industry proposals for evaluation on Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements within the 2nd Generation RLV program
Contract award Plan: January 2001	Award multiple industry contracts for Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems elements within the 2nd Generation RLV program

ACCOMPLISHMENTS AND PLANS

In FY 2001, the 2nd Generation RLV Program will solicit industry in the three major areas of Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems. Current planning calls for industry to respond to NASA by October 2000 with proposals consistent with the program objectives. Multiple contract awards are planned for January 2001. NASA will pursue risk reduction efforts that will enable at least two competing architectures and considers new design RLVs and Shuttle derived concepts. NASA centers will contribute to the effort according to their areas of expertise and in accordance with an overall integrated industry/NASA approach. The competing concepts must address NASA requirements while optimizing the convergence with commercial opportunities. Industry and government partnerships will be established to assure that the ownership and availability of technological advances will be with the implementing contractors.

Acquisition strategy for NGLS is currently underway. Marshall Space Flight Center has been assigned responsibility for this acquisition targeted to take advantage of commercially developed launch systems that to date have little to no demonstrated flight experience. Contracts are targeted for award later in 2000, with first launches feasible within 12-18 months of contract award, dependent on readiness of commercial launch services. These funds will enable the Agency to take advantage of commercially developed alternative access to space for select science and space station mission requirements. Funds will also be used to accommodate definition of mission unique requirements for candidate science and space station missions, in advance of launch service commitments. As the NGLS acquisition develops, NASA envisions the funding for this effort to transition from the Aerospace technology appropriation to the Human Space Flight (HSF) appropriation, which is the lead organization for the NGLS acquisition and where the International Space Station program resides.

BASIS OF FY 2001 FUNDING REQUIREMENT

X-33

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
X-33	277,299	111,600	---

PROGRAM GOALS

The X-33 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level.

STRATEGY FOR ACHIEVING GOALS

NASA is utilizing an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. As a result of industry's leadership of the program, the participants are not playing traditional roles, with government overseeing and directing the work of the industry contractors. Instead, government participants are acting as partners and subcontractors, performing tasks for industry because industry believes that these government team members offer the most effective means to accomplish the program objectives. The government participants report costs and manpower to the industry team leader, as would any other subcontractor. The industry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs, and increased management efficiency.

The X-33 program Phase II selection was made in July 1996 based on specific programmatic, business planning, and technical criteria. NASA selected the Lockheed Martin Skunk Works to lead an industry team to develop and flight test the X-33.

The X-33 is an integrated technology effort to flight-demonstrate key Single Stage To Orbit (SSTO) technologies, and deliver advancements in: 1) ground and flight operations techniques that will substantially reduce operations costs for an RLV; 2) lighter, reusable cryogenic tanks; 3) lightweight, low-cost composite structures; 4) advanced Thermal Protection Systems to reduce maintenance; 5) propulsion and vehicle integration; and, 6) application of New Millennium microelectronics for vastly improved reliability and vehicle health management. X-33 will combine its results with the successes of the DC-XA, X-34 and complementary ground technology advances to reduce the technical risk of full-scale development of an operational RLV. The X-33 test vehicle will fly 13-15 times the speed of sound and will test the boundaries of current technology. Together, the DC-XA, X-34, and X-33 will provide a number of flight tests of key technology demonstrations prior to the decision to privately finance the development and operations of the next generation RLV system.

It is envisioned that private industry will have a primary role in the funding, development, and operation of a next-generation launch system. Therefore, business venture plans are as critical to the RLV program as any technical advancements made on the experimental vehicles. Programmatic and business plans for an operational commercial RLV, expressed in innovative industry-developed and /led business plans, will receive equal consideration with technology demonstrations in future decisions on developing an operational launch vehicle. These plans will address policy and legislative issues as well as private financing options, and will inform the Second Generation RLV decision.

SCHEDULE AND OUTPUTS

X-33 LH_2 Tank Delivery Plan: March 1999 Actual: April 1999	Completes design, manufacture, test and delivery to MSFC. Delayed because of tank redesign activities and issues with main joint fabrication/testing.
X-33 Thermal Protection System (TPS) Delivery Plan: December 1999 Revised: May 2000	Delivery of complete Thermal Protection System for X-33 flight demonstrator. Manufacturing process revised to improve producibility.
X-33 Vehicle to Roll out Plan: January 2000 Revised: Under Review	X-33 flight demonstrator vehicle rollout enabling final checkout. Delayed due to LH_2 tank failure. Failure investigation underway. Schedule impact will be determined after completion of investigation.
X-33 First Flight Plan: July 2000 Revised: Under review	The flight test program, based at Edwards Air Force Base, will fly at speeds greater than Mach 13. Delayed due to LH_2 tank failure. Failure investigation underway. Schedule impact will be determined after completion of investigation.

ACCOMPLISHMENTS AND PLANS

In FY 1999, the X-33 launch complex was completed and site activation begun. In addition, the structural testing of the liquid oxygen tank was successfully completed; the flight software was delivered and verification with validation continuing; the linear aerospike engine was delivered to Stennis and testing begun; the metallic TPS was flight qualified; and the liquid hydrogen composite tank was delivered to MSFC for testing. Three cryogenic and structural load tests of the hydrogen tank, based upon 105 % of maximum flight conditions, were completed. However, after the completion of the third test, a partial failure of the outer skin on one of the four lobes was observed. A failure investigation of the hydrogen tank, by a team of government and industry personnel, was initiated. Both NASA and the contractors remain fully committed to the X-33 program. The failure investigation team will make a report on the root cause of the failure in FY 2000. After reviewing the team's findings, NASA and the contractor will jointly agree on the approach necessary to recover from the hydrogen tank failure and then proceed with the development and execution of a recovery plan and schedule.

BASIS OF FY 2001 FUNDING REQUIREMENT

X-34 and Future X - Pathfinder

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Future X/Pathfinder	71,500	71,800	55,000

PROGRAM GOALS

The objective of the Future-X Pathfinder Program is to flight demonstrate advanced space transportation technologies through the use of flight experiments and experimental vehicles. The Program supports the 1996 National Space Transportation Policy's goal of dramatically reducing the cost of access to space through the development and flight demonstration of advanced space transportation technology. The Program leverages NASA's Space Transfer and Launch Technology (STLT) base research program which develops and ground demonstrates emerging core and focused space transportation technologies. The Program seeks to substantially reduce the cost of space access and to support commercial requirements, NASA mission NASA –unique 2nd Generation RLV requirements, unique, and Department of Defense space transportation requirements.

The Future-X Pathfinder Program is aligned within NASA's Office of Aero-Space Technology (OAT) Enterprise, and supports the strategic goals of OAT's third pillar, Access to Space. Specific Access to Space Pillar goals are to achieve a ten-fold reduction in the cost of placing payloads in low-Earth orbit in the next decade and an additional ten-fold cost reduction in the decade beyond. Future-X Pathfinder will also support a wide range of technology requirements for Earth-to-orbit and in-space transportation systems. Future-X Pathfinder will provide flight-tested technologies needed for lower cost, more reliable, simpler, and more operable space transportation systems.

The program utilizes innovative, streamlined and efficient management practices to accomplish frequent, high-quality demonstrations of precompetitive technologies with high payoff potential. The demonstrations and experiments will be conducted in a fashion that will promote the technology objectives to the fullest extent possible while maintaining sound engineering judgment.

STRATEGY FOR ACHIEVING GOALS

As part of NASA's core mission to advance the state-of-the-art in aeronautics and space transportation, the Agency will continue to develop and demonstrate advanced technologies through the use of experimental flight vehicles. The primary objective of this "Future X" program is to flight demonstrate technologies that can dramatically reduce the cost and increase the reliability of reusable space launch and orbital transportation systems. Future-X Pathfinder demonstrations build on STLT technologies by

carrying out small-scale flight demonstrations every 12-24 months. Pathfinder projects demonstrate cutting-edge technologies with high payoff potential and are typically funded at between $1M and $150M.

The strategy behind flight demonstrators is driven by the need to force technologies and vehicle/system configurations from the laboratory or the computer screen into "real world" operating environments and demonstrate technologies, streamlined management, and operational procedures which can dramatically reduce space transportation system costs. Ground tests can simulate technology in a near-real-world environment but the "reality of flight" compels the program team to understand how each component technology functions as an integral part of the overall flight system. This approach drives a maturity level in, and provides a validation of, the technology and configuration development that cannot be achieved in any other test environment. Future-X Pathfinder demonstrations will be used to validate those technologies and vehicle/system configurations which must be flown to allow their application to existing and future space transportation systems.

The program currently includes the development and operation of the Pathfinder class X-vehicles (X-34 and X37) and a number of flight experiments. The program includes the development and flight demonstrations of a modular orbital flight testbed called the X-37 which will be the first experimental vehicle to be flown in both orbital and reentry environments.

The X-34 project will demonstrate technologies necessary for a reusable vehicle, but will not be a commercially viable vehicle itself. It will be a rocket-powered, Mach-8-capable flight demonstrator test bed to close the performance gap between the subsonic DC-XA and the Mach 13+ X-33. The X-34's objective is to enhance U.S. commercial space launch competitiveness through the development and demonstration of key technologies applicable to future, low-cost reusable launch vehicles. The X-34, now planned to fly for the first time in early 2000, will demonstrate flexible integration capability, high flight rate (25 flights per year), autonomous flight operations, safe abort capability, and a recurring flight cost of $500,000 or less. The X-34 program is procuring two flight vehicles, in keeping with the usual practice in X-vehicle programs, to ensure that the program meets its objectives without constraining the aggressiveness of the demonstration effort. Additionally, a third vehicle is being upgraded from structural test article to unpowered flight vehicle.

The fixed-price X-34 contract is being conducted by Orbital Sciences Corp. of Dulles, Virginia. NASA's Ames, Langley, Dryden, Marshall, Kennedy and White Sands complexes and Holloman Air Force Base all contribute to in the program. The government's work responsibilities include primary propulsion development, thermal protection system integration, wind tunnel support, and testing and flight operations.

The X-34 program has exercised an option for an additional 25 flights (total of 27 flights). The flight test plan includes flying unpowered flights in New Mexico, envelope expansion flights at Dryden Flight Research Center, and an operational flight series at Kennedy Space Center. These flights will demonstrate key embedded technologies and systems operations, as well as additional technology experiments and test articles. X-34 modifications and experiments will benefit from being comparatively small, thereby lowering the expense and risk of demonstrating the technologies, and making their integration into the vehicle less costly. The low-cost X-34 demonstrator will increase the scope and aggressiveness of flight demonstrations, thus increasing the return to the RLV program.

In addition to the ongoing X-34 project, NASA selected proposals and began funding new Pathfinder-class demonstrations in FY 1999. One new Pathfinder demonstrator and seven flight experiments were selected for initiation in FY 1999. Several of the selected experiments are still being negotiated, and details will be provided at a later time. These selections and future ones will enable NASA to continue pushing the state of the art in launch vehicles by demonstrating technologies that lead to increased safety and reliability while reducing cost. The selected Pathfinders include:

- the X-37 Space Plane technology testbed. This demonstrator vehicle is a modular orbital flight testbed which will be flown in both orbital and reentry environments;
- a Hall-effect Solar Electric Thruster system flight demonstration of new onboard in-space propulsion technologies;
- an experiment to demonstrate an onboard intelligent planning system for autonomous abort;
- an experiment to demonstrate technologies that will significantly reduce the access-to-space costs of small payloads;
- an experiment to demonstrate advanced technologies for an integrated vehicle health management system;
- an experiment to demonstrate ultra-high temperature ceramics for reusable, sharp hypersonic leading edges;
- an experiment to demonstrate propulsion technologies that will reduce the weight and size of advanced cryogenic upper stages;
- an experiment to demonstrate advanced in-space propulsion technologies using an electrodynamic tether.

SCHEDULE AND OUTPUTS

Conduct CDR on ProSEDS Plan: August1999 Actual: August 1999	Propulsive Small Expendable Deployer System (ProSEDS) tether flight experiment successfully passed Critical Design Review.
X-34 First Unpowered Flight Plan: September 1999 Revised: April 2000	The flight test program will expand in increments to assure success. Delayed due to longer than expected in vehicle fabrication, specifically the composite tank and flight wing.
X-34 First Powered Flight Plan: December 1999 Revised: August 2000	The flight program will expand the flight profile with initial, unpowered flights to be followed by powered flights that will reach Mach 8. Delayed due to delays in vehicle fabrication, specifically the composite tank and flight wing.

X-37 Roll out Plan: September 2001	X-37 Roll out
X-37 Atmospheric Drop test (unpowered) Plan: January 2002	
X-37 First Orbital Flight Plan: September 2002	
SHARP B2 final design Plan: February 2000	Successfully completes Final Design Review
SHARP B2 Launch Plan: June 2000	Sharp B2 launched on Minuteman III launch vehicle and recovered. Validates sharp, passive, Ultra High Temperature Ceramic (UHTC) leading edge in relevant entry environments
ProSEDS Complete Plan: December 2000	Device will deploy a 5-kilometer (km) bare wire tether coupled to a 10-km nonconducting tether. Earth's magnetic field will accelerate the wire and raise / lower orbit of a Delta II second stage. To be flown as a secondary payload on Delta II upper stage in August 2000
Delivery of IVHM experiment Plan: June 2001	The Integrated Vehicle Health Monitoring (IVHM) experiment is delivered for installation on X-34 vehicle A-3

ACCOMPLISHMENTS AND PLANS

X-34: The **X-34** project completed several critical milestones in FY 1999, including:

- completed independent NASA Safety and Mission Assurance review;
- delivered X-34 vehicle (A-1);
- X-34 roll out;
- completed X-34 System Verification Review;
- completed first X-34 Captive Carry Test.

In FY 2000, modifications to the A-1 vehicle will be completed. This upgraded vehicle, designated A-1A, will then undergo tow testing at Dryden/Edwards AFB. Following tow testing, the A-1A will undergo unpowered flight testing at White Sands Space Harbor. The

A-2 vehicle will be delivered to White Sands, New Mexico to support vehicle static hot-fire testing with the Fastrac engine followed by initial powered flight testing in late summer.

In FY 2001, assembly and testing of the third X-34 vehicle will be completed and delivery to DFRC will take place. Envelope expansion flights will begin (8-9 flights) at Dryden/Edwards AFB with the A-2 vehicle. Also, the building and refurbishment of Fastrac engines to support powered flights will continue.

X-37: In FY 1999, the next generation of technology flight demonstration was initiated through the selection, announced in December 1998, of a new Advanced Technology Vehicle (ATV), now known as X-37, and seven experiments. Final agreement on the X-37 and on several of the experiments was completed in FY 1999. Agreements on a number of the others are in work and will be completed in FY 2000. The Future X Pathfinder Program completed several critical milestones in FY 1999, including:

- awarded a cooperative agreement for the development of the X-37;
- completed the X-37 Kickoff Meeting;
- conducted Critical Design Review for the Propulsive Small Expendable Deployer System (ProSEDS) tether flight experiment;
- completed the X-37 System Requirements Review;
- completed the Preliminary Design Review for the SHARP-B2 ceramic thermal protection system experiment.

In FY 2000, final agreements for the remaining experiments will be negotiated and work initiated on these projects. The PDR for the Cryogenic Propellant Gauge experiment will be completed and launch of the ProSEDS experiment will occur. The Final Design Review for the SHARP-B2 experiment will be completed and the experiment will be launched on a Minuteman III launch vehicle. The contract for the Small Payload Experiment will be awarded. Modifications to the X-40A vehicle will be completed and drop tests (approach and landing tests) will begin at Edwards AFB as a precursor to the X-37 unpowered drop tests. Design and fabrication of the X-37 vehicle will continue and the Final Design Review will be completed. Additionally, X-37 Shuttle integration analyses will continue.

In FY 2001, the X-40A ALT flights will be completed and X-37-Shuttle integration analyses will continue. X-37 vehicle assembly, integration and testing will be completed, the X-37 vehicle will be rolled out, and pre-flight ground tests will begin. The ProSEDS experiment will be completed and delivery of the IVHM flight hardware for the X-34 (vehicle A-3) will occur.

	FY 1999	FY 2000	FY 2001
Integrated Space Transportation Program	**524,599**	**582,700**	**730,000**
2nd Generation RLV Program	365,299	183,400	290,000
Systems Engineering & Requirements Definition			50,000
RLV Competition & Risk Reduction			95,000
NASA-Unique Systems			50,000
Alternative Access			40,000
X-33	277,299	111,600	
On-Going Pathfinders (ends in FY 02)	71,500	71,800	55,000
X-34	*35,500*	*40,500*	*17,900*
X-37	*24,400*	*20,400*	*33,100*
Other Pathfinder Projects	*11,600*	*10,900*	*4,000*
Bantam	16,500		
Technology Base Program*	34,300	107,500	193,600
Future Space Launch Studies	30,000	30,000	
Shuttle Upgrades (HSF)	95,000	186,800	156,400
CRV Phase 1 (HSF)		75,000	90,000

* Technology Base Program as defined in this table includes all activities that directly or synergistically contribute to meeting space transportation technology goals.

BASIS OF FY 2001 FUNDING REQUIREMENT

AERO-SPACE TECHNOLOGY INVESTMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Education Program	---	---	2,000
Minority University Research and Education Program	(7,000)	(7,200)	9,200
Total	---	---	11,200

The Aero-Space Technology Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Aero-Space Technology Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Aero-Space Technology Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY **COMMERCIAL TECHNOLOGY PROGRAMS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Commercial Programs	33,498	35,049	29,200	
Technology Transfer Agents	12,200	7,356	5,800	
Small Business Innovation Research Programs	94,654	97,600	100,000	
Total	140,352	140,005	135,000	
Johnson Space Center	14,725	15,473	14,393	
Kennedy Space Center	7,398	6,111	5,466	
Marshall Space Flight Center	20,075	20,874	20,536	
Stennis Space Center	3,638	3,704	4,986	
Ames Research Center	11,994	13,329	13,238	
Dryden Flight Research Center	3,619	3,659	4,941	
Langley Research Center	17,413	17,167	16,087	
Glenn Research Center	23,321	23,953	21,129	
Goddard Space Flight Center	30,411	30,849	29,338	
Jet Propulsion Laboratory	3,082	2,916	2,916	
Headquarters	4,676	1,970	1,970	
Total	140,352	140,005	135,000	SAT 4.2-2

BASIS OF FY 2001 FUNDING REQUIREMENT

COMMERCIAL TECHNOLOGY PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Commercial Programs	33,700	35,049	29,200
Baseline Commercial Programs	(28,700)	(29,100)	(29,200)
Special Interest Projects	(5,000)	(5,949)	--
Technology Transfer	12,200)	7,356	5,800
Baseline Tech Transfer Agents	(7,200)	(5,800)	(5,800)
Special Interest Projects	(5,000)	(1,556)	--
Small Business Innovative Research Program	94,452	97,600	100,000
Total Commercial Technology Programs	140,352	140,005	135,000

PROGRAM GOALS

NASA's Commercial Technology Program includes Commercial Programs, Technology Transfer Agents and the Small Business Innovative Research (SBIR) Program. NASA's Commercial Technology Program facilitates the transfer of NASA inventions, innovations, discoveries or improvements developed by NASA personnel or in partnership with industry/universities to the private sector for commercial application leading to greater U.S. economic competitiveness.

The goal of Commercial Programs is to share the harvest of NASA's technology programs with the U. S. industrial/scientific community. The goal encompasses the commercialization of technology developed in all the Agency's Enterprises, in past as well as current programs. The NASA Commercial Program mission includes a variety of mechanisms for achieving its goals: partnerships with industry/academia; federal/state/local alliances; emphasis on commercialization in new R&D procurements; electronic commerce; training and education of NASA employees/contractors; employee accountability; and application of performance goals/metrics.

The goal of Technology Transfer Agents is to facilitate the transfer of NASA and other federally sponsored research and technology (and associated capabilities) to the U. S. private sector for commercial application. The purpose of this program goal is to enhance U. S. industrial growth and economic competitiveness.

The goal of NASA's Small Business program is to promote the widest possible award of NASA research contracts to the small business community as well as to promote commercialization of the results of this research by the small business community. Established by Congress, the SBIR program (which includes NASA's Small Business Technology Transfer (STTR) programs) helps NASA develop innovative technologies by providing competitive research contracts to U.S.-owned small businesses.

STRATEGY FOR ACHIEVING GOALS

Commercial Programs

Commercial Programs introduces a new way of doing business that involves a mix of practices/mechanisms which enable the Agency to more closely align its way of doing business with that of the private sector. The common denominator in these practices is technology partnerships. Technology partnerships are business arrangements among the government, industry, and/or academia wherein each party commits resources to the accomplishment of mutually agreed upon objectives and shares the risks and rewards of the endeavor.

The success of Commercial Programs is accomplished through:

- An extensive outreach program (technology dissemination and marketing);
- An electronic commerce/information network (via the Internet) that greatly facilitates the transfer of technology and allows very efficient implementation of our technology business contacts and services;
- Training and education of NASA employees to emphasize program relevance to national needs and to facilitate program implementation; and
- The use of metrics that address day-to-day management processes as well as bottom-line results.

Technology Transfer Agents

Technology Transfer Agents facilitate the transfer/use of NASA and other Federally sponsored research and technology (and associated capabilities) to the U. S. private sector for commercial application to enhance U. S. industrial growth and economic competitiveness. Technology Transfer Agents include funding for the National Technology Transfer Center (NTTC) at Wheeling Jesuit College in West Virginia and the TechLink Center at Montana State University.

In conformance with Congressional direction, NASA has funded the NTTC since 1990. The NTTC serves as a national resource for the transfer and commercialization of federal research and technology. A key, on-going strategy is to align and integrate NTTC operations with the NASA Commercial Technology Programs in support of the NASA Commercial Technology Mission. This strategy provides a foundation upon which the NTTC may fulfill its national role through technology transfer programs funded by other federal agencies and the provision of cost-recovery products and services. Accordingly, NASA has facilitated the involvement of other federal agencies to leverage and extend NTTC capabilities funded by NASA and has enabled the NTTC to implement cost-recovery activities in support of the overall federal technology transfer mission. The NTTC performs four core roles: (1) Serve as a national gateway for federal technology transfer and commercialization, assisting U. S. industry to locate and access NASA and other federally-sponsored technology resources and sources of technical/business assistance; (2) Assess NASA and other federal technologies for commercial potential, and facilitate partnerships for technology commercialization; (3) Develop and deliver professional-level training in technology transfer and commercialization for NASA, federal agencies and other public and private sector audiences; and (4) Promote U. S. industry awareness and utilization of NASA and other federally sponsored research and technology resources available for commercial purpose.

Also in conformance with Congressional direction, NASA funded a 4-year cooperative agreement with Montana State University (in FY 1996) to establish and operate the TechLink Center, a rural technology transfer and commercialization center. The mission of

the TechLink Center is to assist firms and targeted industries in Montana, North Dakota, South Dakota, Wyoming and Idaho to utilize and commercialize technologies from NASA, federal laboratories and universities.

Small Business Innovative Research Program

The Small Business Innovation Research (SBIR) program helps NASA develop innovative technologies by providing competitive research contracts to U.S.-owned small businesses. The program is structured in three phases. Phase I is the opportunity to establish the feasibility, technical merit, and NASA mission need of a proposed innovation. Selected competitively, Phase I contracts have a term of six months and currently do not exceed $70,000. Phase II is the major R&D effort in SBIR. The most promising Phase I projects are selected to receive contracts worth up to $600,000 and have a term of up to two years. Approximately 50 percent of Phase I projects are approved for Phase II. Phase III is the completion of the development of a product or process to make it marketable. SBIR program funding cannot be used to support the Phase III program. Private sector investment and sales of products and services based on the SBIR technology is the usual source of Phase III funding.

SCHEDULES & OUTPUTS

Commercial Programs

FY 1999	Plan	Actual/Revised
Assess approximately 100% of NASA technology for commercial application.	December 1998	December 1998
Expand training program for NASA R&D program managers	September 1999	September 1999
FY 2000		
Increase percentage of NASA R&D invested in commercial partnerships with a goal of achieving 15-20 percent.	December 1999	December 1999
Complete deployment of quarterly automated metrics reporting module at all NASA centers.	June 2000	
Complete deployment of electronic new technology reporting (eNTRe) at all NASA centers.	September 2000	
FY 2001		
Update commercial assessment of NASA activities	December 2000	
Increase partnership percent to 20 percent	December 2000	
Incorporate NASA facilities as integral part of commercial assessment process.	December 2000	

Technology Transfer Agents

FY 1999	Plan	Actual/Revised
Deliver, through a partnership between the NTTC and NASA, 10 Commercial Technology training courses in FY 1999.	September 1999	September 1999
Service a minimum of 16,000 inquiries and produce at least 750 qualified referrals for NASA technologies in FY 1999.	September 1999	September 1999
Increase the assessment/partnering between NASA and industry. Complete 25 in-depth commercialization potential assessments of NASA technologies. .	September 1999	September 1999
Facilitate venture financing for 10 NASA SBIR firms.	September 1999	September 1999
Assist partnering agreements for 10 NASA technologies.	September 1999	September 1999
FY 2000		
Deliver, through a partnership between the NTTC and NASA, 10 Commercial Technology training courses in FY 2000.	September 2000	
Service a minimum of 16,000 inquiries and produce at least 750 qualified referrals for NASA technologies.	September 2000	
Complete 25 in-depth commercialization potential assessments of NASA technologies.	September 2000	
Facilitate the formation of licensing/partnership agreements for 10 NASA technologies.	September 2000	
Facilitate/broker 7 technology partnerships involving regional firms/organizations and NASA technology, research/technology objectives or capabilities.	May 2000	
FY 2001		
Deliver, through a partnership between the NTTC and NASA, 10 Commercial Technology training courses in FY 2001.	September 2001	
Service a minimum of 16,000 inquiries and produce at least 750 qualified referrals for NASA technologies.	September 2001	
Complete 25 in-depth commercialization potential assessments of NASA technologies.	September 2001	
Facilitate the formation of licensing/partnership agreements for 10 NASA technologies.	September 2001	
Facilitate/broker 7 technology partnerships involving regional firms/organizations and NASA technology, research/technology objectives or capabilities.	May 2001	

Small Business Innovative Research Program

FY 1999	Plan	Actual/Revised
Complete development and issue the FY 1999 SBIR Phase I solicitation via the internet.	April 1999	April 1999
Electronic submission of proposals via the internet.	July 1999	July 1999
Select and announce new SBIR Phase II awards resulting from the FY 1998 solicitation.	September 1999	September 1999
FY 2000		
Select and announce SBIR FY 1999 Phase I awards.	October 1999	October 1999
Complete development and issue the FY 2000 SBIR Phase I solicitation.	April 2000	
Complete automated processing from solicitation to proposal evaluation.	August 2000	
Select and announce SBIR FY 1999 Phase II awards	August 2000	
FY 2001		
Select and announce SBIR FY 2000 Phase I awards.	October 2000	
Complete development and issue the FY 2001 SBIR Phase I solicitation.	April 2001	
Select and announce SBIR FY 2000 Phase II awards	August 2001	

ACCOMPLISHMENTS AND PLANS

Commercial Programs

In FY 1999, the emphasis of Commercial Programs was on showing steady improvement toward increasing the percentage of the NASA R&D budget in commercial partnerships. Piloting the distance learning project and delivering several classroom training sessions with increased NASA participation helped foster the Agency's internal culture change and further improved commercial technology program performance. Also in FY 1999, deployment of electronic new technology reporting (eNTRe), which provides innovators and researchers a secure desktop tool for identifying and reporting new technologies and innovations, was initiated. In conformance with FY 1999 Congressional direction pertaining to appropriation action, the following was initiated: (1) Established the Women/Minority program in partnership with the HUD Enterprise Zone program which leverages the NASA TechTracS electronic commerce activity; (2) Partnered with Florida Technology Research & Development Agency (TRDA) to support the expansion of technology incubators in Florida, and with the Montana Big Sky Economic Development Authority which has launched an incubator in Billings, MT; and (3) Expanded the Glenn Research Center Garrett Morgan project to increase the outreach and support to the small, minority business community in the mid-west region.

In FY 2000, commercial partnerships with industry will increase and the technology and partnership database will be refined, updating it to include new Agency contracting efforts and describe new technologies that will be made public via the electronic network. Increase the percentage of the NASA R&D budget in commercial partnerships with industry to approach 20 percent in FY 2000. Continue to improve the utilization of the Internet as an electronic marketplace for NASA technology assets, facilitating technology transfer and commercialization opportunities between U.S. industry and NASA. Expand training opportunities focused on commercial technology strategy and its implementation within NASA's management training program. Establish a pilot project to create Strategic Technology Development Partnerships with one non-aerospace industry sector to meet the goal of establishing joint-sponsored R&D projects with industry to share risk and cost in the development of new technologies critical to NASA missions.

The following Congressional programmatic activities will be performed in FY 2000: (1) continuation of the Software Optimization and Reuse Program (SORT), which was created to institutionalize and systemize process-driven, domain-specific, architecture-centric software reuse technology in NASA; (2) establishment of a cooperative relationship with the newly-created NASA Illinois Commercialization Center (NICC) and the Illinois Coalition,; (3) the Miami-Dade Community College will establish a technology-oriented business incubator in the Homestead region; and, (4) development (in partnership with FEMA, NOAA, National Weather Service, AirTouch and AEPTEC) of a large-scale personal warning system which will serve as an alert to national disasters.

NASA plans to maintain 20 percent of the NASA R&D budget in commercial partnerships with industry in FY 2001. NASA plans to have a fully operational Commercial Technology Training syllabus and curriculum accessible by NASA employees. The Commercial Program plans to expand services offered to each of the four NASA Enterprises and establish Multi-Center Technology Development Partnerships with at least two non-aerospace industry sectors to meet the goal of establishing joint-sponsored R&D projects with industry that will share risk and cost in the development of new technologies critical to NASA missions.

Technology Transfer Agents

The National Technology Transfer Center (NTTC) is a national resource for NASA and federal technology transfer and commercialization. The NTTC performed as a national gateway for NASA technology, servicing 16,000 inquiries and producing 450 qualified leads versus the 750 planned qualified referrals. The decrease in qualified leads was due to increased lead screening to yield higher potential opportunities. The NTTC completed 25 in-depth commercialization potential assessments of NASA technologies and facilitated venture financing for 10 NASA SBIR firms, and qualified and assisted licensing/partnering agreements for 10 NASA technologies. NTTC's technology transfer activities will continue under the newly established cooperative agreement

TechLink facilitated 15 technology partnerships with regional firms/organizations and NASA research technology. TechLink brokered and supported a partnership between NASA/JSC and a Montana biotechnology firm, leading to the discovery of the extreme gamma radiation resistant qualities of a micro-organism and derived compounds that have significant potential for NASA and commercial applications, including the "hardening" of space electronics. Also to TechLink's credit, TechLink facilitated/brokered 9 additional partnerships involving other federal technology, for a total of 24 partnerships (versus the goal of 15).

In FY 2000, 10 technology commercialization training sessions/events are to be delivered to NASA personnel, including Internet-based training, to implement required skills and best practices throughout NASA. The NTTC performs as a national gateway for

NASA technology, servicing 16,000 inquiries for NASA technology and producing 450 qualified referrals to NASA centers for technology transfer/commercialization partnerships. The NTTC is to complete, in-depth commercialization potential assessments of 25 NASA technologies and assist the formation of licensing/partnership agreements for 10 NASA technologies. The NTTC plans to facilitate/broker 7 technology partnerships involving regional firms/organizations and NASA technology, research/technology objectives or capabilities by May 2000.

The following Congressional programmatic activities will be performed in FY 2000: (1) continuation of the Garret-Morgan initiative in Ohio to assist in the establishment of Women-Owned/Minority-Owned Businesses; and (2) an augmentation to the NTTC.

In FY 2001, the NTTC will deliver 10 technology commercialization training sessions/events to NASA personnel, including Internet-based training, to implement required skills and best practices throughout NASA. The NTTC will continue to perform as a national gateway for NASA technology, servicing almost 20,000 inquiries for NASA technology and producing almost 500 qualified referrals to NASA centers for technology transfer/commercialization partnerships. The NTTC will complete in-depth commercialization potential assessments of 25 NASA technologies, and assist the formation of licensing/partnership agreements for at least 10 NASA technologies. The TechLink Center will continue to assist firms and targeted industries in Montana, North Dakota, South Dakota, Wyoming and Idaho to utilize and commercialize technologies from NASA, federal laboratories and universities.

Small Business Innovative Research Program

In accordance with the Small Business Innovation Development Act of 1982, the actual SBIR funding level for the Agency is determined based on the results of a detailed analysis of the actual obligations for the most recent fiscal year that data is available. For FY 1999 and FY 2000, the funding levels are based on actual data. For FY 2001, the funding level shown for SBIR is a placeholder that is used for planning purposes only. In early FY 2001, the Office of the Comptroller will perform a detailed assessment on the Agency's most recent actual data. If the results of the assessment conclude that the actual SBIR funding level varies from the budgeted amount, that change will be reflected in the Agency's initial operating plan to Congress.

The NASA SBIR program has contributed to the U. S. economy by fostering the establishment and growth of over 1,100 small, high technology businesses. More than 430 private ventures have been initiated based on NASA SBIR programs. Over one hundred of the SBIR Phase II firms have produced Phase III agreements generating at least $1 million per firm in new revenues.

In FY 1999, a commercialization survey of all companies receiving NASA SBIR Phase II awards between 1983 and 1994 was completed. Approximately 125 SBIR FY 1997 Phase II research proposals were selected for award in January 1999. The selected projects totaled approximately $73 million and were conducted by 113 small, high-technology firms located in 26 states. Selection of 345 research proposals for awards for NASA's SBIR FY 1998 Phase I Solicitation was completed in October 1998. The solicitation for SBIR FY 1999 Phase I was issued on schedule in April 1999. Over 99 percent of Phase I proposals were submitted online and processed electronically as opposed to the 50 percent in FY 1998.

The FY 1999 NASA SBIR solicitation included 25 major topic areas divided into 94 sub-topics. The description of each of these sub-topics is developed by various NASA installations to include current and foreseen Agency program needs and priorities. NASA typically receives over 2,000 proposals. For each solicitation, proposals are evaluated by the NASA field centers for scientific and technical merit, key staff qualifications, soundness of the work plan, and plans for commercial application. NASA Headquarters

(HQ) program offices provide additional insight regarding commercial, program balance, and critical Agency requirements. Selections are made by NASA HQ, based upon these recommendations, and other considerations. NASA continues to extensively utilize the Internet to administer the program. NASA also provides information for public access via a bulletin board service and other Internet information servers. Moreover, NASA continues to increase it's use of the Internet and information technology in it's operational processes including the development of the technical solicitation sub-topics; for public release of the solicitation in a variety of electronic formats; and for proposal evaluation. The end-to-end electronic solicitation process is serving as a resource not only within NASA, but is being viewed as a prototype for other government agencies. One of the four stated purposes of the SBIR program is to "Emphasize the program goal of increasing private sector commercialization of technology developed through federal research and development" (P.L. 102-564, Small Business Research and Development Enhancement Act of 1992). According to the U.S. Small Business Administration's SBIR Policy Directive, commercial feasibility of an SBIR proposal is a selection criteria requirement.

Several other innovations continued to strengthen small business programs. External evaluation of each proposal's ultimate commercial potential is now a foundational part of the selection process. In addition, a comprehensive survey of past SBIR projects' Phase III commercialization and/or mission application continues to be conducted. The information from the review/survey will be used to identify critical predictors of commercial viability and, therefore, be used to increase the effectiveness of the program's commercialization efforts. Finally, the process of mapping several sub-topics into specific NASA mission applications continues to be a focus for strategic planning activities, with the intent to more closely tie the SBIR program with the primary mission needs of each NASA Enterprise.

In FY 2000, the commercialization survey will be extended to include commercial results for Phase II's awarded by NASA in 1995. Approximately 290 SBIR FY 1999 Phase I awards will be reviewed and selected by October 1999. Approximately 190 SBIR FY99 Phase II awards will be reviewed and selected by August 2000. It is our intent to achieve a 100 percent fully automated process, from proposal receipt to final report submission, pending adoption of federal & NASA electronic signature standards.

In FY 2001, the commercialization survey will be extended to include commercial results for Phase II's awarded by NASA in 1996/97. The FY 2000 SBIR Phase I awards will be selected by October 2000. The SBIR FY 2000 Phase II awards will be selected by August 2001.

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **MISSION COMMUNICATIONS SERVICES**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Ground Networks	211,200	162,000	--	SAT 5-4
Mission Control and Data Systems	143,100	233,800	--	SAT 5-11
Space Network Customer Services	25,700	10,500	--	SAT 5-21
Total	380,000	406,300	--	
Distribution of Program Amount by Installation				
Johnson Space Center	119,700	171,900	--	
Kennedy Space Center	--	1,100	--	
Marshall Space Flight Center	300	1,400	--	
Dryden Space Flight Center	12,600	12,800	--	
Glenn Research Center	10,100	10,100	--	
Goddard Space Flight Center	101,800	71,800	--	
Jet Propulsion Laboratory	132,400	131,900	--	
Headquarters	3,100	5,300	--	
Total	380,000	406,300	--	

Note -- Beginning in FY 2001, funding for these activities will be moved to the Space Operations program under the Science, Aeronautics, and Technology Appropriation.

PROGRAM GOALS

The Mission Communications Services goal is to provide high quality, reliable, and cost effective space operations services which enable Enterprise mission operations. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center, in Houston, Texas manages the telecommunication, data processing, mission operations, and mission planning services needed to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. The SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participating with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for space operations services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests. The content described in this section represents the Mission Communications Services portion of the SOMO responsibilities.

The Mission Communications Services segment of NASA's Space Communications program is composed of Ground Networks, Mission Control and Data Systems, and Space Network Customer Service. These programs establish, operate, and maintain NASA ground networks, mission control, and data processing systems and facilities to provide communications service to a wide variety of flight programs. These include deep space and Earth-orbital spacecraft missions, research aircraft missions, and sub-orbital flights. Mission support services such as orbit and attitude determination, spacecraft navigation and maneuver support, mission planning and analysis and other mission services are provided. New communications techniques, standards, and technologies for the delivery of communication services to flight operations teams and scientific users are developed and applied. Agency spectrum management and data standards coordination for NASA are conducted under this program.

STRATEGY FOR ACHIEVING GOALS

The Space Operations program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the evaluation and coordination of data standards and communication frequencies to be used in the future.

The Space Operations program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the evaluation and coordination of data standards and communication frequencies to be used in the future.

Many science and exploration goals are achieved through inter-agency or international cooperation. NASA's Space Operations assets are provided through collaborative agreements with other U.S. Government agencies, commercial space enterprises, academia, and international cooperative programs. Consistent with the National Space Policy, NASA procures commercially available goods and services to the fullest extent feasible, NASA develops selected technologies which leverage commercial investments and enable the use of existing and emerging commercial telecommunications services to meet NASA's Space Operations needs. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems and services.

The Consolidated Space Operations Contract (CSOC) was successfully implemented on 1 January 1999 under the direction of the Space Operations Management Office and Lockheed Martin Space Operations Company as the Prime Contractor. CSOC provides end-to-end space operations mission and data services to both NASA and non-NASA customers. CSOC is a $3.44B contract with a Basic Period of Performance from January 1999 through December 2003 and an option period though December 2008. The contract is a Performance Based Cost Plus Award Fee (CPAF) with possible conversion to Fixed Price Incentive Fee (FPIF) within 2 years. A total of nine contracts were consolidated at the inception of CSOC, a further four contracts have been consolidated in FY 2000 to date and two further contracts are to be consolidated in FY 2001. CSOC reflects a significant change in NASA philosophy as accountability and day to day direction for providing space operations services shifts from NASA to the CSOC contractor.

Beginning in FY 2001, funding for these activities will be consolidated with Space Communication Services, currently part of the Mission Support appropriation, as the Space Operations program under the Science, Aeronautics, and Technology Appropriation. This is being done so as to link these activities more directly with the agency programs that constitute the principal users of these facilities and services. This will enable the Space Operations Management Office (SOMO) at Johnson Space Center to more effectively manage the Space Operations program. This will ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. A set of budget crosswalk tables between the Space Communication Services and Mission Communications Service budget and the consolidated Space Operations program is described in the <u>Special Issues</u> section.

BASIS OF FY 2001 FUNDING REQUIREMENT

GROUND NETWORKS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Deep Space Network – Systems	70,400	74,700	--
Deep Space Network – Operations	53,800	53,300	--
Spaceflight Tracking and Data Network - Systems	1,000	300	--
Spaceflight Tracking and Data Network - Operations	7,700	3,600	--
Aeronautics, Balloons, and Sounding Rockets - Systems	5,100	6,100	--
Aeronautics, Balloons, and Sounding Rockets - Operations	19,300	21,400	--
Total	157,300	159,400	--

PROGRAM GOALS

The Ground Networks program goal is to provide high quality, reliable, cost-effective ground-based tracking, command and data acquisition systems and services for NASA science and aeronautics programs. Launch, emergency communications, and landing support for the Space Shuttle is also provided by the Ground Networks facilities. The program provides for the implementation, maintenance, and operation of the tracking and communications facilities necessary to fulfill program goals for the NASA flight projects. The Ground Networks program also supports NASA programs in collaborative interagency, international, and commercial enterprises and independently provides support to other national, international, and commercial enterprises on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

The Ground Networks program is comprised of the following elements: the Deep Space Network (DSN), managed by the Jet Propulsion Laboratory (JPL); the Spaceflight Tracking and Data Network (STDN), managed by the Goddard Space Flight Center (GSFC); the Aeronautics, Balloon and Sounding Rocket (AB&SR) tracking and data acquisition facilities managed by GSFC/Wallops Flight Facility (WFF); and the Western Aeronautical Test Range (WATR), managed by the Dryden Flight Research Center (DFRC). As the prime contractor for the CSOC, the Lockheed-Martin Space Operations Company became responsible for providing space operational services beginning in January 1999.

Re-engineering efforts will continue on the STDN facilities, resulting in reduced operation and maintenance costs. NASA terminated S-band and C-band services at the Bermuda station in November 1998, following completion of two Space

Shuttle modifications. One permits earlier communications through the Tracking and Data Relay Satellite (TDRS) during the launch phase of the mission and the second allows onboard use of the GPS to replace the use of ground radar for Space Shuttle navigation. UHF Command services were terminated in FY 1999. The UHF air-to-ground voice service remains available for Space Shuttle launch operations.

The number of missions serviced by the DSN facilities and the requirements of the individual missions will increase dramatically over the next several years. In anticipation of the increases, new antenna systems have been developed and obsolete systems are expected to be phased out or converted for alternate uses. The DSN has been reconfigured with four new 34-meter antenna systems located at Goldstone, California; Canberra, Australia; and Madrid, Spain. These 34-meter antennas will enable the expanded coverage requirements and provide simultaneous coverage of two deep space missions that are in critical phases. Currently, a 34-meter antenna transferred from the U.S. Army located at Goldstone is supporting the Solar Observatory for Heliospheric Observations spacecraft. An 11-meter antenna system has been installed at each DSN complex to provide science support for the Institute of Space and Astronautical Science (ISAS) Japanese VLBI Space Operation Program (VSOP) spacecraft.

The DSN has several on-going re-engineering efforts. These new processes allow the DSN to increase the tracking hours delivered while reducing costs. The processes include giving a single operator end-to-end control of the entire data acquisition process, redesigning systems that provide support data to allow automation and quicken response time, developing a process to better define DSN services which will allow customers to choose only the services necessary to support the mission, and providing systems support data which allow greater automation and quicker response time.

The DSN is the premier facility for tracking deep space probes and is occasionally supplemented by the facilities of other agencies or nations. NASA is actively working with industry to foster the enhancement of existing "commercial-off-the-shelf" (COTS) data processing systems to expand their applicability so that inexpensive and reliable communications services can be readily obtained for the new small-class missions. Future earth orbiting missions will be supported by commercially available tracking systems, enabled by such tools as the Very Large Scale Integration (VLSI) High-Rate Frame Synchronization and Data Extraction chips which have been transferred to industry.

New Ground Networks capabilities include two 11-meter antenna systems installed near Fairbanks, Alaska and at Svalbard, Norway to provide command and data acquisition support for the expanded number of Earth-observing missions which includes EOS AM-1 and Landsat-7. Also, the Low Earth Orbit Terminal (LEO-T) contract has been expanded to provide three autonomous 5-meter ground stations for space science mission support. The first of these systems was installed in Puerto Rico and supported the Far Ultraviolet Spectroscopy Explorer (FUSE) mission in FY 1999.

The Ground Networks program, in conjunction with other NASA elements, is demonstrating and implementing Global Positioning System (GPS) flight units on NASA-sponsored missions. This demonstration seeks to minimize future tracking and navigation activities. The Student Nitric Oxide Explorer (SNOE) mission demonstrates these new capabilities using commercial flight units as the primary source of this function. The Western Aeronautical Test Range is striving for even

more efficiency as it provides NASA's capability for tracking, data acquisition, and mission control for a wide variety of flight research vehicles. The WATR provides both on-orbit and landing support to the Space Shuttle and communications with the Mir Space Station. Intense planning is underway to support the Reusable Launch Vehicle (X-33) and other wide range of vehicles with WATR resources.

NASA will pursue commercial ground tracking services for low-Earth orbit missions. Transition activities to the commercial operator began in FY 1999. Upon successful completion of transition activities, the 26-meter subnet will be operated at a reduced level until FY 2001 in order to meet prior project support commitments. The DSN will return to servicing only deep space missions, highly elliptical Earth orbiting missions, launch and early orbit phase, ground-based radio astronomy, and planetary radar astronomy activities.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Deep Space Network					
Number of NASA missions	52	46	51	45	--
Number of hours of service	92,000	93,000	84,000	84,000	--
Ground Network					
Number of Space Shuttle launches	7	4	8	4	--
Number of NASA/Other ELV launches	26	38	25	45	--
Number of NASA Earth-Orbiting missions	30	33	37	32	--
Number of Sounding Rocket deployments	30	25	25	27	--
Number of Balloon deployments (scientific)	26	26	26	26	--
Number of hours of service (GN Orbital Tracking)	23,750	26,000	25,200	23,000	--
Western Aeronautical Test Range					
Number of NASA missions	1,100	905	1,200	N/A	--
Number of NASA research flights	750	200	350	N/A	--
Number of Hours of Mission Control Center Support	N/A	N/A	1,450	1,450	

CONSOLIDATED SPACE OPERATIONS CONTRACT (CSOC)

Phase 1 Contract Award	May 1997
Phase 2 Proposal Due	January 1998
Phase 2 Contract Award	October 1998
Phase 2 Phase-In	October-December 1998
Phase 2 CSOC In Force	January 1999

The CSOC measures of performance apply to the Ground Networks, Mission Control Data Systems, and Space Network Customer Services.

ACCOMPLISHMENTS AND PLANS

The Deep Space Network (DSN) provided over 90,000 hours of tracking support to 49 missions during FY 1999. The year was unusually active with many critical events requiring support. These included 17 launches of NASA, NASA cooperative, and reimbursable spacecraft. The NASA support included the launches of DS1, MCO, MPL, Stardust, QuickSCAT, and the small explorers: SWAS, WIRE, and FUSE. The DSN also supported numerous encounters, including Galileo's continuing encounters with the moons of Jupiter, DS1's asteroid encounter, the Cassini Venus flyby and Earth swing-by, Planet-B Earth flyby, and the NEAR asteroid encounter. Special tracking coverage was provided more than 19 times in support of spacecraft emergencies and anomalies. Missions receiving this special support included DS1, MGS, Stardust, ACE, Galileo, NEAR, SOHO, TDRS, MPL, and GOES. During this busy year, DSN performance levels continued to exceed requirements, with delivery of scheduled telemetry data exceeding 98%.

JPL engineers worked with SOMO and its industry contract partners to ensure that the integrated operations architecture design will meet the needs of deep space missions while reducing life cycle costs. In particular, a new high-level control architecture was defined for the DSN. This new service-oriented Deep Space Missions System architecture was successfully applied to DS1, MGS, and Stardust.

JPL has also been working to decrease the Deep Space Network's complexity and improve equipment reliability, thereby enabling substantial DSN operations and maintenance cost savings. Efforts along these lines include Y2K certification, improved network control, network simplification, upgrades to the 26-meter antenna subnet, replacement of aging electronics systems, and decommissioning of obsolete antennas.

During FY 1999, over 400 program elements associated with the DSN were subjected to a rigorous Y2K certification process involving the examination of 8 million source lines of code within the DSN itself and another 8 million lines of code in the advanced multi-mission operations system.

Development of the Network Control Project (NCP) was mostly completed in FY 1999 with deployment scheduled to start during the first quarter of FY 2000. Deployment of NCP will facilitate workload reductions at the antenna stations and establish the infrastructure for modernization, automation, and reduction in operations cost.

The Network Simplification Project (NSP) has continued on schedule. NSP consolidates or replaces all the telemetry and radiometric DSN equipment with new technology and COTS solutions that enable advanced capabilities and remote operations. The objectives include replacing failure-prone aging assemblies, reducing system interfaces, reducing manual

switches, replacing old NASA-unique protocols with industry standards, and providing new deep space mission command services to eliminate labor-intensive controller functions.

Major elements of the effort to replace aging DSN electronics include accelerated deployment of the Block V Exciters and the microwave controller. The new exciters replace 20-to-30 year old suites of uplink processing equipment -- increasing reliability, decreasing maintenance, and accommodating the pursuit of higher frequency, Ka-band communications. The microwave controller provides for computer control, allowing automation and reducing operations costs.

Implementation has begun on the telecommunications roadmap that was developed in FY 1998. The roadmap laid out a plan for using new technologies to increase the DSN's deep space communications capabilities to accommodate a growing exploration fleet while maximizing the utility of the existing DSN antennas. The first major goal of this implementation will be the addition of Ka-band reception capability on all of the DSN's 34-meter beam wave-guide antennas. An implementation plan was developed in FY 1999 that has successfully passed a preliminary definition and cost review, and has moved on to prototyping activities for certain key technologies. One of these technologies currently under test is a single microwave feed horn and associated cryogenic low-noise amplifiers that can receive both X-band (8 GHz) and Ka-band (32 GHz) simultaneously. The other significant effort undertaken as part of the telecommunications roadmap is the completion of the DSS-26 34-meter antenna at Goldstone. The electronics for this antenna are being developed and installed to make this antenna operational in FY 2001.

Additional upgrades of the unique 70 meter antennas were made to avoid obsolescence issues and develop an improved transmit capability. The 70 meter X-band Uplink task will implement a higher power transmit capability to better communicate with spacecraft in the outer solar system. The 34-meter antenna-arraying task is also nearing completion. This task has already demonstrated the improved performance achievable through the use of an array of multiple antennas and will be operational in early FY 2000.

The Ground Network (GN) is comprised of tracking stations in Alaska, Bermuda, Merritt Island (MILA), McMurdo, and Wallops Island. The GN also supports critical Space Shuttle launch, emergency communications, and landing activities. The GN provides for the implementation, maintenance, and operation of the tracking and communications facilities necessary to fulfill program goals for flight projects in the NASA mission set. Missions supported also include NASA inter-agency collaborative programs, commercial enterprises, and other national, international, and commercial enterprises on a reimbursable basis. The Space Shuttle launches were successfully supported through dedicated facilities of the MILA station and the Ponce de Leon inlet annex. The continuation of this support, further enabled by the implementation of the re-engineered STDN system elements, is expected throughout FY 2000 and FY 2001.

The aging 9-meter hydraulic antennas at MILA are being replaced with electric drive systems, capable of functioning without an operator. Efforts in support of this initiative will begin in FY 2000 and be completed in FY 2001. Infusion of technology developed in support of receiver, exciter, and ranging subsystems will be introduced in a phased manner to replace aging subsystems at MILA and Ponce de Leon throughout FY 2000.

The Wallops Flight Facility (WFF) completed the installation of the 11-meter telemetry antenna systems at the Poker Flat Research Range near Fairbanks, Alaska and at Svalbard, Norway in preparation for support of the QuikSCAT and Landsat-7 missions in FY 1999. Ground station and network integration and certification testing was completed in FY 1999. The systems are scheduled to be officially transitioned to CSOC for operations, maintenance, logistics, and sustaining engineering in FY 2000. NASA is planning for the future of the McMurdo Ground Station (MGS) in Antarctica. The drivers for this station are the need to provide for predictable performance of MGS in support of Launch and Early Orbit Operations, to provide for supplemental Earth Observing System (EOS) Polar Ground Network (EPGN) support, and to pursue a mutually beneficial relationship with the U. S. Air Force with regard to improved service and cost sharing. Concept definition, project plans, and approval to proceed were granted in FY 1999. Upcoming plans for MGS in FY 2000 include the implementation of a Joint Operations Center (JOC) with the U. S. Air Force and subsystem upgrades in support of the EOS missions.

Work will continue on the replacement of the Wallops Range Data Acquisition and Computational System; this system is a range safety tool and is obsolete and expensive to maintain. Work on the 11-meter antenna system enhancements required to support the Advanced Earth Orbiting Satellite (ADEOS) II mission will be completed in FY 2001.

The Ka-Band Ground Terminal Development activity will begin in FY 2000. This effort will seek to demonstrate the commercial viability of providing high rate ground data acquisition in the Ka-Band area. This activity will include participation by members from various NASA centers and commercial vendors.

The NASA Dryden Flight Research Center (DFRC) Western Aeronautical Test Range (WATR) provides communications, tracking, data acquisition, and mission control for a wide variety of aeronautic and aerospace vehicles. The WATR meets widely diverse research project requirements with tracking, telemetry, and communication systems and control room complexes. Due to the nature of the aeronautical research mission, it is essential to respond to new project requirements within days or weeks rather than months or years, and to do so safely, efficiently, and economically. To accomplish this, WATR facilities, systems, and processes are designed to support a wide range of requirements, be easily reconfigured (less than one hour for control rooms), to be shared between multiple projects, and to readily interface with specialized equipment brought in by our customers. This approach provides the needed agility to be responsive while reducing costs to individual customers by increasing utilization rates. Customers of the WATR facilities include other NASA Centers, the U.S. Army, U.S. Air Force, U.S. Navy, Federal Aviation Administration, and the aerospace industry.

BASIS OF FY 2001 FUNDING REQUIREMENTS

MISSION CONTROL AND DATA SYSTEMS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Mission Control - Systems	10,000	9,700	--
Mission Control - Operations	142,800	182,700	--
Data Processing - Systems	42,900	41,000	--
Data Processing - Operations	17,300	8,600	--
Total	213,000	242,000	--

PROGRAM GOALS

The Mission Control and Data Systems program goal is to provide high-quality, reliable, cost-effective mission control and data processing systems and services for spaceflight missions; data processing, and flight dynamics services for NASA flight projects. The program provides for data systems, telecommunications systems technology demonstrations, and coordination of data standards and communications frequency allocations for NASA flight systems. The Mission Control and Data Systems program provides for the launch and early orbit implementation, maintenance, and operation of the mission control and data processing facilities necessary to ensure the health and safety and the sustained level of high quality performance of NASA flight systems. The program provides and demonstrates key technologies and innovative approaches to satisfy Strategic Enterprises' mission needs and to maximize NASA's ability to acquire commercial services that meet its communications and operations needs. Through these efforts, the program also seeks to promote sustained U.S. economic and technological leadership in commercial communications.

STRATEGY FOR ACHIEVING GOALS

The Mission Control and Data Systems program, primarily managed by the GSFC, is comprised of a diverse set of facilities, systems and services necessary to support NASA flight projects. The Lockheed Martin Space Operations Company was awarded the Consolidated space Operations Contract (CSOC) and became the primary contract responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The mission control function consists of planning scientific observations and preparing command sequences for transmission to spacecraft to control all spacecraft activities. Mission Operations Centers (MOC's) interface with flight dynamics and communications network, and science operations facilities in preparation of command sequences, perform the real-time uplink of command sequences to the spacecraft systems, and monitor the spacecraft and instrument telemetry for

health, safety, and system performance. Real-time management of information from spacecraft systems is crucial for rapid determination of the condition of the spacecraft and scientific instruments and to prepare commands in response to emergencies and other unplanned events, such as targets of opportunity.

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOCs) for the Hubble Space Telescope (HST) program; the International Solar Terrestrial Physics (ISTP) Wind, Polar, and Solar Observatory for Heliospheric Observation (SOHO); Rossi X-ray Timing Explorer (RXTE), TOMS-Earth Probe (EP), Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX); Fast Auroral Snapshot (FAST); Transport Region and Coronal Explorer (TRACE); and Submillimeter Wave Astronomy Satellite (SWAS) missions, and the Multi-satellite Operations Control Center (MSOCC) which supports the Compton Gamma Ray Observatory (CGRO), Upper Atmosphere Research Satellite (UARS), Extreme Ultraviolet Explorer (EUVE), and Earth Radiation Budget Satellite (ERBS) missions. The Advanced Composition Explorer (ACE) and Tropical Rainfall Measurement Mission (TRMM) are also operated out of GSFC MOC's. Data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) and Extreme Ultraviolet Explorer (EUVE) missions.

The CGRO has phased into the TPOCC architecture of distributed workstations first used for the International Monitoring Platform (IMP-8) mission. NASA's SAMPEX, FAST, and Submillimeter Wave Astronomy Satellite (SWAS) missions will be operated from a common control facility for Small Explorer missions. The SWAS Mission Operations Center has been completed. The Wide Field Infrared Explorer (WIRE) control center has also been completed. These workstation systems will allow for increased mission control capability at reduced cost.

The first launch of a Medium-class Explorer (MIDEX) is currently scheduled for January 2000. Approximately one spacecraft per year will be launched, with potentially every other MIDEX mission operated from GSFC, dependent on successful Principal Investigator teaming arrangements. To minimize operations costs, plans for the MIDEX missions include consolidating the spacecraft operations, flight dynamics and science data processing all into a single multi-mission control center. Many of the functions will be automated using a commercial expert system product. The control center system will be used for spacecraft integration and test, thereby eliminating the need and cost of unique spacecraft manufacturers integration and test systems.

Other mission control systems include the Space Shuttle Payload Operations Control Center (POCC) Interface Facility and the Command Management System. The Space Shuttle POCC Interface Facility (SPIF) is being upgraded with a low-cost, PC-based front-end data system now operating in shadow mode. The SPIF provides a single interface to the Mission Control Center for use of spacecraft mission control facilities to access spacecraft deployed by the Space Shuttle. The Command Management System generates command sequences to be used by mission control centers. A User Planning System, currently being upgraded to a workstation-based environment compatible with the Network Control Center (NCC) configuration, is provided for scheduling communications with spacecraft supported by the Tracking and Data Relay Satellite System (TDRSS); and the Flight-to-Ground Interface Engineering Center provides flight software pre-flight and in-flight simulation and development support for GSFC flight systems. An Operations Support Center maintains status records of in-flight NASA systems.

The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data prior to its distribution to science operations centers and to individual instrument managers and research teams.

Data processing facilities include the Packet Data Processing (PACOR) facility, the Data Distribution Facility, and the Telemetry Processing Facility. The PACOR facility utilizes the International Consultative Committee for Space Data Systems data protocol to facilitate a standardized method of supporting multiple spacecraft. PACOR provides a cost-effective means of processing flight data from SAMPEX, EUVE, CGRO, SOHO, SWAS, RXTE, TRMM, and HST spacecraft missions. The transfer of EUVE to the University of California at Berkley in FY 1998 and the relocation of CGRO processing to the workstation-based PACOR II in FY 1998 resulted in the closure of the older PACOR I system.

The Data Distribution Facility (DDF) performs electronic and physical media distribution of NASA space flight data to the science community. The DDF has been a pioneer in the use of Compact Disk-Read Only Memory technology for the distribution of spacecraft data to a large number of NASA customers. Specialized data processing services are provided by the Telemetry Processing Facility for the ISTP missions (Wind, Polar, and Geotail). The Spacelab Data Processing Facility located at the MSFC, processes data from Space Shuttle payloads. Specialized telemetry processing systems for NASA's Space Network is also provided under this program.

The Mission Control and Data Systems program provides for the operation, sustainment, and improvement of NASA's Flight Dynamics Facility (FDF). Funding for the FDF is used to: provide orbit and attitude determination for operating NASA space flight systems, including the Tracking and Data Relay Satellite (TDRS) and the Space Shuttle; develop high-level operations concepts for future space flight systems; modify existing FDF systems to accommodate future missions; develop mission-unique attitude software and simulator systems for specific flight systems; generate star catalogues for general use; and conduct special studies of future orbit and attitude flight and ground system applications. It is critical to continuously know the location of spacecraft so as to communicate with the system and to know the orientation of the spacecraft to assess spacecraft health and safety and to perform accurate scientific observations. The type and level of support required by spacecraft systems is dependent on the design of its on-board attitude and control systems, including its maneuver capabilities, and the level of position and pointing accuracy required of the spacecraft. Automated orbit determination systems for TDRS and other spacecraft systems are also under development.

Besides the operation of currently deployed spacecraft and the modification and development of mission control and data processing systems to accommodate new flight systems, the program also supports the study of future flight missions and ground system approaches. Mission control and first-order data processing systems are less costly systems. Yet, proper economy of mission planning requires solutions that integrate ground and flight system development considerations. Special emphasis is given by the Mission Control and Data Systems program to seeking integrated solutions to spacecraft and ground systems designs that emphasize spacecraft autonomy; higher data transmission and processing rates; ease and low cost of operation; reuse of software; and selected use of advanced hardware and software design techniques to increase the return of space flight system investments at equal or lower cost than is required to support today's mission systems.

The Mission Control and Data Systems program supports advanced technology development at GSFC, JPL and GRC. The GSFC team, including contractors and universities, provides advanced technology in several area such as tracking and data acquisition future systems, communications and telemetry transport, and advanced space systems for users. Anticipating a future mission set characterized by large numbers of rapid, low-cost missions, the JPL team invests in technologies that can increase the overall capacity-to-cost ratio for the Deep Space Network. Efforts are focused on core technologies unique to, and critical for, deep space telecommunications, tracking and navigation, and radio science. Current technology areas include antenna systems, low noise systems, frequency and timing, radio metric tracking, navigation, network automation, atmospheric propagation and optical communications. The Glenn Research Center team identifies, develops, and demonstrates advanced radio frequency antennas, amplifiers, receivers, digital communications and hybrid network technologies and services for use in NASA missions and commercial systems.

The Mission Communication Services advanced technology development has three forms that include near term (1-3 years) demonstration and application of data management and telecommunications technology and procedures, mid-range (3-5 years) development of ground and space flight communications systems; and a long-term, pre-competitive technology development and demonstration make up. Consideration of innovative applications of commercial "off-the-shelf" (COTS) technology is emphasized. Such applications often open new market opportunities to suppliers of these technologies resulting from their NASA experience. Additionally, in response to White House National Space Policy, NASA is planning to transition its communications operations to commercial services. Technology developments and demonstrations focus on technology and service gaps to enable utilization of commercially provided services.

A critical element of the Mission Control and Data Systems program is the securing of adequate frequency spectrum resources which are required in the performance of all flight missions, piloted and unpiloted, including spectrum for all active emitters as well as passive sensors. GRC, in concert with NASA Headquarters Office of Space Flight, manages these resources for the Agency and coordinates frequency spectrum requirements with other federal agencies, industry and regulatory bodies to obtain all requisite authorizations to operate telecommunications systems associated with NASA programs. Consistent with its charter pursuant to both the Space Act of 1958 and the Communications Satellite Act of 1962, NASA also serves, as an advocate for obtaining the unique frequency spectrum allocations required by the commercial sector to exploit satellite technology for future generation telecommunications systems. In compliance with the 1992 Telecommunications Authorization Act, NASA actively participates in the Interdepartment Radio Advisory Committee to establish National and International spectrum management policies.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Number of NASA spacecraft supported by GSFC mission control facilities	22	25	23	25	--
Number of mission control hours of service (thousands)	66,000	57,300	67,000	62,000	--
Number of billions of bits of data processed	64,500	N/A	67,000	N/A	--
Number of NASA/Other missions provided flight dynamics services	44	47	49	49	--
Number of NASA/Other ELV launches supported by flight dynamics services	34	37	22	22	--

ACCOMPLISHMENTS AND PLANS

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOC) for the Hubble Space Telescope (HST) program; the International Solar Terrestrial Physics (ISTP) Wind, Polar, and Solar Observatory for Heliospheric Observation (SOHO); Rossi X-ray Timing Explorer (RXTE), Total Ozone Mapping Satellite-Earth Probe (EP), Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX); Transport Region and Coronal Explorer (TRACE); the Compton Gamma Ray Observatory (CGRO); and Submillimeter Wave Astronomy Satellite (SWAS) missions, and the Multi-satellite Operations Control Center (MSOCC) which supports Upper Atmosphere Research Satellite (UARS) and Earth Radiation Budget Satellite (ERBS) missions. The Advanced Composition Explorer (ACE), Tropical Rainfall Measurement Mission (TRMM), the International Monitoring Platform (IMP-8), and Land Satellite (Landsat-7) are also operated out of GSFC MOCs. Data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) mission. Mission control of the Fast Auroral Snapshot (FAST) mission was operated under CSOC during FY 1999 and transitioned to the UCB beginning FY 2000. The path finder success of the earlier transition of EUVE mission operations was the basis for the FAST transition.

The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data (Level 0) prior to its distribution to science operations centers and to individual instrument managers and research teams.

Flight dynamics services were provided to all NASA space flight missions that utilize NASA's Space Network and to selected elements of the Ground Network, including the Space Shuttle, Expendable Launch Vehicles, and satellite systems. Attitude software and simulator development was provided for the TRACE, ACE, and TRMM flight systems.

The Mission Control and Data Processing area has pursued proactive measures to consolidate functions, close marginal facilities, and reduce overall contractor workforce to reflect the Agency's goals. Examples include the transition of both the SAMPEX and FAST MOC operations to ITOS workstation systems and the outsourcing of FAST mission operations to the

UCB, the completion of the ISTP Reengineering consolidation of Wind and Polar operations with SOHO to be completed in FY 2000, and the use of automation to monitor routine spacecraft health and safety functions to enable smaller flight operations teams and reduced operations schedules (RXTE, CGRO, Landsat-7, etc.).

Transfer of data systems technologies to flight project use occurred in the areas of software reuse, expert system monitoring and command of spacecraft functions, and packet data processing systems. Software reuse, expert systems, workstation environments, and object-oriented language applications continued. The Mission Control and Data Systems upgrades areas will continue to integrate modern technology into mission operations support systems through the use of systems like the GenSAA for automation, software-based telemetry front-end processing systems and the Mission Operations Planning and Scheduling System, case-based and model-based reasoning tools, and commercial orbit planning systems.

Significant development, test, and pre-launch support associated with the MIDEX and SMEX missions are part of the Mission Control and Data Systems activity. Emphasis upon commercial products, artificial intelligence applications and advanced graphical displays will be continued in FY 2000 for application in MIDEX and future SMEX missions. Evolution of systems to a single integrated mission control, command management, flight dynamics, and first-level science processing system will continue. The Flight Dynamics Facility (FDF) operations concept to perform routine operations as integral functions within mission control centers will also continue into FY 2000. New flight dynamics technology development and infusion for autonomous space and/or ground spacecraft navigation and control will be major efforts.

Preparations for the HST Third Servicing Mission in FY 2000 will continue, including the delivery of the Vision 2000 ground system, delivery of the new flight control computer flight software, and the payload computer ACS support system. Development efforts will continue in preparation for the MIDEX MAP mission that is scheduled to launch in FY 2001.

The Mission Operations and Data Systems upgrades efforts will continue to focus efforts on operations automation beyond the RXTE Automated Mission Operations System (AMOS), the CGRO Reduced Operations by Optimizing Tasks and Technologies (ROBOTT), and the automation provided for TRACE to promote single shift staffing for operations. Mission Control and Data Systems will actively lead and participate in establishing new architecture directions and rapid prototyping, exploring system autonomy concepts, and use of commercial-off-the-shelf products.

Mission Control and Data Systems upgrades area will continue the lead in scoping and prototyping innovative architectures such as: the use of Transmission Control Protocol/Internet Protocol or Space Communications Protocol Standards for ground and flight communications; the use of knowledge-based control languages; ground and space autonomy; and active endorsement and collaboration in formulating a Space Objects technology for adoption and implementation of plug-and-play components for mission operations. Exploration of the promise of advanced communications technologies will continue throughout this period.

Development for Triana and MAP will be completed in FY 2001; developments will continue for the MIDEX and SMEX series as well as for the HST Servicing Mission 3B. Development efforts on Triana, MAP, EO-1, and similar missions will realize benefits from

modern technology, commercial products, and more cost-effective processes (for example, a single system to perform spacecraft integration and test and mission operations; skunkworks development teams; concurrent engineering).

The flight dynamics work will continue to be provided in the areas of ground support system development, analysis, and automation tools.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE NETWORK CUSTOMER SERVICES

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Space Network Customer Services	9,700	4,900	--

PROGRAM GOALS

The goal of the Space Network Customer Service program is to provide high quality, reliable, cost-effective customer access to the multi-mission space telecommunications network serving all TDRS-compatible Earth orbiting and suborbital flight missions and to provide network control and scheduling services to customers of both the Space Network and selected Ground Networks elements.

STRATEGY FOR ACHIEVING GOALS

This program develops and maintains both the management and technical interfaces for customers for the Space Network. The Network Control Center (NCC), located at the Goddard Space Flight Center in Maryland, is the primary interface for all customer missions. The primary function of the NCC is to provide scheduling for customer mission services. In addition the NCC generates and transmits configuration control messages to the network's ground terminals and TDRS satellites and provides fault isolation services for the network. The Customer Services program also provides comprehensive mission planning, user communications systems analysis, mission analysis, network loading analysis, and other customer services and tests to insure network readiness and technical compatibility for in-flight communications.

The Lockheed Martin Space Operations Company was recently awarded the Consolidated Space Operations Contract (CSOC) and will be the primary contractor responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The Customer Services program also undertakes network adaptations to meet specific user needs and provides assistance to test and demonstrate emerging technologies and communications techniques. A low power, portable transmit/receive terminal, called Portcom, which operates with TDRS spacecraft has been demonstrated. Potential applications include data collection from remote sites where commercial capabilities do not exist, such as NOAA ocean research buoys and National Science Foundation (NSF) Antarctic activities. A series of tests are being conducted with Japanese and European satellites and data acquisition communications systems for mutual provision of emergency operational spacecraft support.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Number of NASA spacecraft events supported by the NCC	99,900	N/A	100,800	N/A	--

ACCOMPLISHMENTS AND PLANS

Implementation was completed on an improved, distributed architecture for the NCC, which is Year 2000 (Y2K) compliant. This Service Planning Segment Replacement (SPSR), provides more efficient use of the network capabilities, improved ability to resolve scheduling conflicts among customer missions, and provides standard commercial protocols for both internal and customer interfaces. The NCC modifications to the scheduling system also incorporated the Request Oriented Scheduling Engine (ROSE) which provides special features for conflict-free spacecraft scheduling, such as goal-directed scheduling and repetitive activities with variable start times and duration. This architectural change was undertaken over several years and accomplished segment by segment. The Communication and Control Segment Replacement (CCSR) development effort, planned as a follow on to the SPSR, was cancelled when analysis indicated that it would not be cost effective in the current environment. Work will be initiated in FY 2000 on various components of the DAS, including Space Network Web-based scheduling; this effort is expected to continue through FY 2001 and become fully operational in FY 2002.

The Ka-Band Ground Terminal Development activity will begin in FY 2000. This effort will seek to demonstrate the commercial viability of providing high rate ground data acquisition in the Ka-Band area. This activity will include participation by members from various NASA centers and commercial vendors. The successful demonstration of this capability is scheduled for late FY 2001. Capabilities to be demonstrated are far beyond what is in operation today. Success will allow NASA and its commercial partners to take advantage of the new frequency allocations for space and earth science and to alleviate issues regarding radio frequency spectrum interference that exist today.

The requested funding also provides for continuation of mission planning, customer requirements definition and documentation, mission and network operational integration, analyses, customer communications systems analyses, test coordination and conduct, and other customer support services in support of Space Shuttle, International Space Station (ISS) and other human space flight efforts.

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **SPACE OPERATIONS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Operations	[333,500]	[326,500]	329,800	SAT 6-4
Mission and Data Service Upgrades	[92,000]	[97,600]	106,200	SAT 6-8
Tracking and Data Relay Satellite System Replenishment Project	[96,900]	[31,700]	55,000	SAT 6-16
Technology	[43,400]	[40,200]	38,400	SAT 6-18
[Reimbursements [non-add]]	[[45,900]]	[[43,000]]	[[43,000]]	
Total	[565,800]	[496,000]	529,400	
Distribution of Program Amount by Installation				
Johnson Space Center	[154,100]	[218,900]	222,300	
Kennedy Space Center	[30,200]	[15,100]	41,700	
Marshall Space Flight Center	[47,200]	[9,100]	11,900	
Dryden Space Flight Center	[12,600]	[12,800]	12,600	
Glenn Research Center	[10,100]	[10,100]	9,000	
Goddard Space Flight Center	[169,300]	[89,300]	94,600	
Jet Propulsion Laboratory	[136,200]	[134,700]	131,100	
Headquarters	[6,100]	[6,000]	6,200	
Total	[565,800]	[496,000]	529,400	

Note - FY 1999 and FY 2000 data in this section are for comparison purposes only. See Mission Communication Services in the SAT section and Space Communications Services in the MS section for more details.

PROGRAM GOALS

The program goal is to provide reliable, quality and cost-effective space operations services that enable Enterprise mission execution. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center in Houston, manages the program to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. In line with the National Space Policy, the SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participate with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for operational communications and associated information handling services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests.

STRATEGY FOR ACHIEVING PROGRAM GOALS

The Space Operations program provides command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university research and laboratory facilities, and the investigating scientists. The program provides scheduling, network management and engineering, pre-flight test and verification, flight system maneuver planning and analysis. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises.

The Space Operations program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the evaluation and coordination of data standards and communication frequencies to be used in the future.

Many science and exploration goals are achieved through inter-agency or international cooperation. Services from NASA's Space Operations assets are provided through collaborative agreements with other U.S. Government agencies, commercial space enterprises, academia, and international cooperative programs. Consistent with the National Space Policy, NASA procures commercially available goods and services to the fullest extent feasible, NASA develops selected technologies which leverage commercial investments and enable the use of existing and emerging commercial telecommunications services to meet NASA's Space Operations needs. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems and services.

The Consolidated Space Operations Contract (CSOC) was successfully implemented on 1 January 1999 under the direction of the Space Operations Management Office and Lockheed Martin Space Operations Company as the Prime Contractor. CSOC provides end-to-end space operations mission and data services to both NASA and non-NASA customers. CSOC is a $3.44B contract with a Basic Period of Performance from January 1999 through December 2003 and an option period though December 2008. The contract is a Performance Based Cost Plus Award Fee (CPAF) with possible conversion to Fixed Price Incentive Fee (FPIF) within 2 years. A total of nine contracts were consolidated at the inception of CSOC, a further four contracts have been consolidated in FY 2000 to date and two further contracts are to be consolidated in FY 2001. CSOC reflects a significant change in NASA philosophy as accountability and day-to-day direction for providing space operations services shifts from NASA to the CSOC contractor.

Space Operations is a new line in the SAT budget, beginning in FY 2001. Funding for these activities is consolidated from Space Communication Services, currently part of the Mission Support account, and Mission Communication Services, currently part of the SAT account. This is being done so as to link these activities more directly with the agency programs that constitute the principal users of these facilities and services. This will enable the Space Operations Management Office (SOMO) at Johnson Space Center to more effectively manage the Space Operations program. This will ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. A set of budget crosswalk tables between the Space Communication Services and Mission Communications Service budget and the consolidated Space Operations program is described in the Special Issues section.

BASIS OF FY 2001 FUNDING REQUIREMENT

OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Space Network	[6,900]	[2,500]	2,400
Deep Space Network	[86,800]	[81,700]	84,100
Ground Networks	[23,600]	[23,300]	22,500
Mission Control and Data Systems	[170,500]	[211,500]	210,500
NASA Integrated Services Network	[45,700]	[7,500]	10,300
Total	[333,500]	[326,500]	329,800

PROGRAM GOALS

Space operations functions are defined as those activities that provide "mission" and "data" services to customers to enable their utilization and exploration of space. The mission and data services goal is to provide high-quality, reliable, cost-effective operations that support planning, system engineering, design, development, and analysis to a large number of NASA missions including planetary and interplanetary missions; human space flight missions; near-Earth and Earth-orbiting missions; sub-orbital and aeronautical test flights.

STRATEGY FOR ACHIEVING GOALS

Mission services provide for the launch and early orbit implementation, maintenance, and operations of the mission control and data processing facilities necessary to ensure the health and safety and the sustained level of high quality performance of NASA flight systems. Mission service operations are conducted in the facilities provided by NASA at multiple locations both in the United States and at overseas sites. Data Services provide command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university facilities, and the investigating scientists.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Deep Space Network					
Number of NASA missions	[52]	[46]	[51]	[45]	47
Number of hours of service	[92,000]	[93,000]	[84,000]	[84,000]	81,000
Ground Network					
Number of Space Shuttle launches	[6]	[4]	[8]	[6]	9
Number of NASA/Other ELV launches	[26]	[38]	[25]	[45]	54
Number of NASA Earth-Orbiting missions	[30]	[33]	[37]	[32]	32
Number of Sounding Rocket deployments	[30]	[25]	[25]	[27]	25
Number of Balloon deployments (scientific)	[26]	[26]	[26]	[26]	26
Number of hours of service (GN Orbital Tracking)	[23,750]	[26,000]	[25,200]	[23,000]	23,000
Western Aeronautical Test Range					
Number of hours mission control center			[1,450]	[1,450]	1,875
Mission and Control Data Services					
Number of NASA spacecraft supported by GSFC mission control facilities	[22]	[25]	[23]	[25]	25
Number of mission control hours of service (in thousands)	[66,000]	[57,300]	[67,000]	[62,000]	62,000
Number of NASA/Other missions provided flight dynamic services	[44]	[47]	[49]	[49]	49
Number of NASA/Other ELV launches supported by flight dynamic services	[34]	[37]	[22]	[22]	22
Other					
NASA Integrated Systems Network - number of locations connected	[410]	[410]	[420]	[420]	420
Number of hours of space network services in thousands	[54,100]	[57,800]	[62,000]	[61,000]	61,000

ACCOMPLISHMENTS AND PLANS

The Space Network is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. In FY 1999, the missions supported included four Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit such as Hubble Space Telescope (HST) and the Compton Gamma Ray Observatory (CGRO), as well as other compatible missions such as Ocean Topography Experiment, Extreme Ultraviolet Explorer (EUVE), Department of Defense customers, the Rossi X-ray Timing Explorer (RXTE), the Starlink research aircraft, Engineering Test Satellite (ETS-VII), Tropical Rainfall Measurement Mission(TRMM), Landsat-7, and the Long Duration Balloon program. The Space Network extended service (on a reimbursable basis) to the expendable launch vehicle community including agreements with US Air Force Titan and Lockheed Martin's commercial Atlas programs. In FY 2000 and FY 2001, the Space Network will continue to provide services to the Space Shuttle Flights and their attached payloads as well as the construction phase of the International Space Station and the Earth Observing System Terra mission.

The Deep Space Network (DSN) provided over 90,000 hours of tracking support to 46 missions during FY 1999. The year was unusually active with many critical events requiring support. These included 17 launches of NASA, NASA cooperative, and reimbursable spacecraft. The NASA support included the launches of DS1, MCO, MPL, Stardust, QuickSCAT, and the small explorers: SWAS, WIRE, and FUSE. The DSN also supported numerous encounters, including Galileo's continuing encounters with the moons of Jupiter, DS1's asteroid encounter, the Cassini Venus flyby and Earth swing-by, Planet-B Earth flyby, and the NEAR asteroid encounter. Special tracking coverage was provided more than 19 times in support of spacecraft emergencies and anomalies. Missions receiving this special support included DS1, MGS, Stardust, ACE, Galileo, NEAR, SOHO, TDRS, MPL, and GOES. During this busy year, DSN performance levels continued to exceed requirements, with delivery of scheduled telemetry data exceeding 98%.

The Ground Network (GN) is comprised of tracking stations in Poker Flats Research Range near Fairbanks, Alaska, Bermuda, Merritt Island (MILA), Svalbard, Norway, McMurdo Ground Station in the Antarctic, and Wallops Island. The GN also supports critical Space Shuttle launch, emergency communications, and landing activities. The GN provides for the implementation, maintenance, and operation of the tracking and communications facilities necessary to fulfill program goals for flight projects in the NASA mission set. Missions supported also include NASA inter-agency collaborative programs, commercial enterprises, and other national, international, and commercial enterprises on a reimbursable basis. The Space Shuttle launches were successfully supported through dedicated facilities of the MILA station and the Ponce de Leon inlet annex. The continuation of this support, further enabled by the implementation of the re-engineered STDN system elements, is expected throughout FY 2000 and FY 2001.

The NASA Dryden Flight Research Center (DFRC) Western Aeronautical Test Range (WATR) provides communications, tracking, data acquisition, and mission control for a wide variety of aeronautic and aerospace vehicles. The WATR meets widely diverse research project requirements with tracking, telemetry, and communication systems and control room complexes. Due to the nature of the aeronautical research mission, it is essential to respond to new project requirements within days or weeks rather than months or years, and to do so safely, efficiently, and economically. To accomplish this, WATR facilities, systems, and processes are designed to support a wide range of requirements, be easily reconfigured (less

than one hour for control rooms), to be shared between multiple projects, and to readily interface with specialized equipment brought in by our customers. This approach provides the needed agility to be responsive while reducing costs to individual customers by increasing utilization rates. Customers of the WATR facilities include other NASA Centers, the U.S. Army, U.S. Air Force, U.S. Navy, Federal Aviation Administration, and the aerospace industry.

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOC) for the Hubble Space Telescope (HST) program; the International Solar Terrestrial Physics (ISTP) Wind, Polar, and Solar Observatory for Heliospheric Observation (SOHO); Rossi X-ray Timing Explorer (RXTE), Total Ozone Mapping Satellite-Earth Probe (EP), Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX); Transport Region and Coronal Explorer (TRACE); the Compton Gamma Ray Observatory (CGRO); and Submillimeter Wave Astronomy Satellite (SWAS) missions, and the Multi-satellite Operations Control Center (MSOCC) which supports Upper Atmosphere Research Satellite (UARS) and Earth Radiation Budget Satellite (ERBS) missions. The Advanced Composition Explorer (ACE), Tropical Rainfall Measurement Mission (TRMM), the International Monitoring Platform (IMP-8), and Land Satellite (Landsat-7) are also operated out of GSFC MOCs. Data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) mission. Mission control of the Fast Auroral Snapshot (FAST) mission was operated under CSOC during FY 1999 and transitioned to the University of California-Berkley beginning in FY 2000. The pathfinder success of the earlier transition of EUVE mission operations was the basis for the FAST transition.

The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data (Level 0) prior to its distribution to science operations centers and to individual instrument managers and research teams.

Flight dynamics services were provided to all NASA space flight missions that utilize NASA's Space Network and to selected elements of the Ground Network, including the Space Shuttle, Expendable Launch Vehicles, and satellite systems. Attitude software and simulator development was provided for the TRACE, ACE, and TRMM flight systems.

NASA Integrated Services Network (NISN) provides for the implementation, maintenance, and operation of the telecommunications services, control centers, switching systems, and other equipment necessary to provide an integrated approach to NASA communications requirements. NISN completed the transition of the NISN Video Teleconferencing Service to the General Services Administration's Federal Telecommunications Services (FTS) 2000 Switched Compressed Video Transmission Service (SCVTS). This video service is shared by several government agencies, provides connectivity to commercial video services such as those provided by Sprint and MCI, and is also compatible to desktop video systems. This transition standardizes NASA video teleconferencing service on the industry standard of voice activated switching, and provides greater access to non-NASA video systems.

BASIS OF FY 2001 FUNDING REQUIREMENT

MISSION AND DATA SERVICES UPGRADES

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Space Network	[5,500]	[1,700]	6,600
Deep Space Network	[34,000]	[39,500]	39,100
Ground Networks	[13,100]	[7,700]	7,400
Mission Control and Data Systems	[39,400]	[48,700]	53,100
Total	[92,000]	[97,600]	106,200

PROGRAM GOALS

The goal of Mission and Data Services Upgrades Project is to enable the conduct of the NASA strategic enterprises by implementing required upgrades to space operations systems and services. Reliable electronic communications and mission control systems are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Mission and Data Services Upgrades Project, one part of NASA's Space Communications program, is composed of Space Network Upgrades, Deep Space Network Upgrades, Ground Network Upgrades, and Mission Control and Data Systems Upgrades. These areas establish, operate, and maintain NASA ground networks, mission control, and data processing systems and facilities to provide communications service to a variety of flight programs. These include deep space, Earth-orbital, research aircraft, and sub-orbital missions. Mission support service facilities that perform functions such as orbit and attitude determination, spacecraft navigation and maneuver support, mission planning and analysis and several other mission services are also upgraded as part of this project. New communications techniques and standards for the delivery of communication services to flight operations teams and scientific users are developed and applied. Data standards coordination for NASA is conducted under this project.

STRATEGY FOR ACHIEVING GOALS

Upgrade tasks are being conducted on the Space Network, the Deep Space Network, the Ground Network, and the Mission Control and Data Systems to enable the conduct of on going and new missions by the NASA strategic enterprises. These upgrades are implemented by the Goddard Space Flight Center, the Jet Propulsion Laboratory, and their respective industry partners.

A major upgrade task for the Space Network has been the recently completed Service Planning Segment Replacement for the Network Control Center (NCC). The NCC, located at the Goddard Space Flight Center in Maryland, provides the primary interface for all customer missions. The primary function of the NCC is to provide scheduling for customer mission services. In addition, the NCC generates and transmits configuration control messages to the network's ground terminals and TDRS satellites and provides fault isolation services for the network. The Mission and Data Services Upgrades Project provides comprehensive mission planning, user communications systems analysis, mission analysis, network loading analysis, and other customer services and tests to ensure network readiness and technical compatibility for in-flight communications.

In the Deep Space Network (DSN) area, JPL is working with its industry contract partners to transform the DSN and associated mission operations system architecture into a service provision system known as the Deep Space Mission System (DSMS). The DSMS will provide a customer-oriented, turnkey service system which seamlessly integrates the facilities of the DSN and the Advanced Multi-mission Operations System (AMMOS). This system will enable more efficient provision of currently available services as well as the creation of entirely new services.

Beyond efficiency improvements to existing assets, NASA is exploring ways to enhance the amount of deep space communications capability that can be applied to servicing the growing exploration fleet. NASA efforts along these lines include international cooperation and technology upgrades to existing assets.

In the international cooperation arena, NASA, through JPL, is working with other space-faring nations to develop a standardized set of communications protocols that will allow spacecraft interoperability with U.S. and foreign ground communications assets. NASA is also working to establish the agreements necessary to utilizing such interoperability – one example under discussion is the possible application of Italy's planned 64 meter Sardinia antenna to the support of some U.S. deep space missions.

In NASA's other effort for supporting the growing exploration fleet, applying technology improvements to existing DSN communications assets, JPL is working to improve capacity through antenna feed enhancements at current radio frequencies and through the application of higher radio, and even optical, frequencies. This will enable significant leaps in the data rates available for future missions. The first major new radio frequency improvements involve the addition of Ka-band reception capability on all of the DSN's 34-meter beam wave-guide antennas. NASA is also working to develop the corresponding Ka-band transmission hardware needed for the flight elements.

The Ground Networks upgrades area, in conjunction with other NASA and commercial elements, is demonstrating and implementing automated ground station control software systems to allow for increased reliability and lower overall operating costs. The completion of the implementation of the autonomous polar ground stations in Alaska and Norway will demonstrate these new capabilities using commercial and in-house developed software systems as the primary source of this function.

Efforts to reduce the cost of operations for low-Earth orbit spacecraft will continue with development of new technology and operational processes and the commercialization of ground based tracking systems. The goal of these efforts is to provide a

low-cost ground tracking capability utilizing either the existing NASA resources or fostering the commercialization of ground tracking services. This concept will be validated by the NASA/CSOC polar tracking services contract recently awarded to the AlliedSignal Technical Services Corporation (ATSC) DataLYNX contractor in support of the EOS Program. Re-engineering efforts will be completed in early FY 2000 on the Ground Network facilities, resulting in reduced operation and maintenance costs. The UHF air-to-ground voice service at the Bermuda station remains available for Space Shuttle launch operations.

The Mission Control and Data Systems upgrades area, primarily managed by the GSFC, is comprised of a diverse set of facilities, systems and services necessary to support NASA flight projects. The mission control function consists of planning scientific observations and preparing command sequences for transmission to spacecraft to control all spacecraft activities. Mission Operation Centers (MOC's) interface with flight dynamics, communications network, and science operations facilities in preparation of command sequences, perform the real-time uplink of command sequences to the spacecraft systems, and monitor the spacecraft and instrument telemetry for health, safety, and system performance. Real-time management of information from spacecraft systems is crucial for rapid determination of the condition of the spacecraft and scientific instruments and to prepare commands in response to emergencies and other unplanned events, such as targets of opportunity. The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data prior to its distribution to science operations centers and to individual instrument managers and research teams.

A major effort within the mission control and data systems is the development of more cost-effective mission operations systems to support the Explorers Program. The first launch of a Medium-class Explorer (MIDEX) is the Imager for Magnetopause-to-Aurora Global Exploration satellite (IMAGE) currently scheduled for February 2000. Approximately one spacecraft per year will be launched, with potentially every other MIDEX mission operated from GSFC, dependent on successful Principal Investigator teaming arrangements. To minimize operations costs, plans for the MIDEX missions include consolidating the spacecraft operations, flight dynamics and science data processing all into a single multi-mission control center. Many of the functions will be automated using a commercial expert system product. The control center system will be used for spacecraft integration and test, thereby eliminating the need and cost of unique spacecraft manufacturers integration and test systems.

SCHEDULES AND OUTPUTS

Space Network - Control Center Communications and Control Segment Replacement Complete Plan: 4th Qtr FY 2000 Revised: Cancelled	The task was cancelled due to insufficient return on investment.

Deep Space Network - Configuration Control Group Upgrade Complete Plan: 4th Qtr FY 2002 Actual: 4th Qtr FY 1999	Replace existing microwave controller hardware used to control the high-powered transmitters in the 34M and 70M antennas to improve safety. Year 2000 compliance for hardware required earlier completion date.
Deep Space Network - Frequency and Timing Monitor and Control Upgrade Complete Plan: 4th Qtr FY 2001 Actual: 4th Qtr FY 1999	Replace existing frequency and timing subsystem control hardware and software to retire non-maintainable equipment and reduce operations costs. Year 2000 compliance for hardware required earlier completion date.
Deep Space Network - DSN 26M Electronics Development Complete Plan: 4th Qtr FY 2001	Automate and upgrade the existing electronics in the 26M antennas to support unattended operations (i.e., no operations staff is nominally required).
Ground Network - McMurdo Ground Station Upgrades Complete Plan: 2nd Qtr FY 2001	Upgrade the existing facility (joint with the USAF) to improve operability during inclement weather and support future cooperation with the USAF.

ACCOMPLISHEMENTS AND PLANS

Space Network Upgrades

Implementation was completed on an improved, distributed architecture for the NCC, which is Year 2000 (Y2K) compliant. This Service Planning Segment Replacement (SPSR), provides more efficient use of the network capabilities, improved ability to resolve scheduling conflicts among customer missions, and provides standard commercial protocols for both internal and customer interfaces. The NCC modifications to the scheduling system also incorporated the Request Oriented Scheduling Engine (ROSE) which provides special features for conflict-free spacecraft scheduling, such as goal-directed scheduling and repetitive activities with variable start times and duration. This architectural change was undertaken over several years and accomplished segment by segment. The Communication and Control Segment Replacement (CCSR) development effort, planned as a follow on to the SPSR, was cancelled when analysis indicated that it would not be cost-effective in the current environment. Work will be initiated in FY 2000 on various components of the DAS, including Space Network Web-based scheduling; this effort is expected to continue through FY 2001 and become fully operational in FY 2002.

The Ka-Band Ground Terminal Development activity will begin in FY 2000. This effort will seek to demonstrate the commercial viability of providing high rate ground data acquisition in the Ka-Band area. This activity will include participation by members from various NASA centers and commercial vendors. The successful demonstration of this

capability is scheduled for late FY 2001. Capabilities to be demonstrated are far beyond what is in operation today. Success will allow NASA and its commercial partners to take advantage of the new frequency allocations for space and earth science and to alleviate issues regarding radio frequency spectrum interference that exist today.

The requested funding also provides for continuation of mission planning, customer requirements definition and documentation, mission and network operational integration, analyses, customer communications systems analyses, test coordination and conduct, and other customer support services in support of Space Shuttle and the International Space Station (ISS).

In FY 1999, work began on the TDRS low power transceiver (LPT) development. This initiative seeks to provide a lower cost, lighter weight and lower power-demanding alternative to today's expensive transponder options for spacecraft telemetry, command, and orbit determination requirements. The multiple-mode nature of the LPT allows for flexible multiple-frequency implementations that also provide for Global Positioning System (GPS) position processing including time determination. Suggested applications include use on smaller satellites, satellite crosslinks and NASA/DOD network interoperability. This effort will continue into FY 2000 with the delivery of a prototype unit and the initiation of flight unit development; completed flight units are planned to be delivered in FY 2001.

Work will begin in FY 2000 on various components of the DAS, including the Third Generation Beam Forming System (TGBFS). The TGBFS development activity was initiated to augment the TDRSS multiple-access (MA) capability and to permit customers to implement new operations concepts incorporating continuous return link communications. The DAS will expand existing Multiple Access (MA) return service capabilities by allowing customers to directly obtain services from the Space Network without scheduling through the Network Control Center (NCC). The TGBFS component is planned to be completed in FY 2001. The DAS will be installed at White Sands, New Mexico, and is expected to be operational and available for customer use in FY 2002.

Deep Space Network Upgrades

JPL engineers worked with SOMO and its industry contract partners to ensure that the integrated operations architecture design will meet the needs of deep space missions while reducing life cycle costs. In particular, a new high-level control architecture was defined for the DSN. This new service-oriented Deep Space Missions System architecture was successfully applied to DS1, MGS, and Stardust.

JPL has also been working to decrease the Deep Space Network's complexity and improve equipment reliability, thereby enabling substantial DSN operations and maintenance cost savings. Efforts along these lines include Y2K certification, improved network control, network simplification, upgrades to the 26-meter antenna subnet, replacement of aging electronics systems, and decommissioning of obsolete antennas.

During FY 1999, over 400 program elements associated with the DSN were subjected to a rigorous Y2K certification process involving the examination of 8 million source lines of code within the DSN itself and another 8 million lines of code in the advanced multi-mission operations system.

Development of the Network Control Project (NCP) was mostly completed in FY 1999 with deployment scheduled to start during the first quarter of FY 2000. Deployment of NCP will facilitate workload reductions at the antenna stations and establish the infrastructure for modernization, automation, and reduction in operations cost.

The Network Simplification Project (NSP) has continued on schedule. NSP consolidates or replaces all the telemetry and radiometric DSN equipment with new technology and COTS solutions that enable advanced capabilities and remote operations. The objectives include replacing failure-prone aging assemblies, reducing system interfaces, reducing manual switches, replacing old NASA-unique protocols with industry standards, and providing new deep space mission command services to eliminate labor-intensive controller functions. The final installations are planned for mid-2002 through 2003. The first-of-a-kind uplink and downlink replacement systems will be installed on a 34-meter beam wave-guide antenna at Goldstone for operational testing during FY 2002.

Major elements of the effort to replace aging DSN electronics include accelerated deployment of the Block V Exciters and the microwave controller. The new exciters replace 20-to-30 year old suites of uplink processing equipment -- increasing reliability, decreasing maintenance, and accommodating the pursuit of higher frequency, Ka-band communications. The microwave controller provides for computer control, allowing automation and reducing operations costs.

Implementation has begun on the telecommunications roadmap that was developed in FY 1998. The roadmap laid out a plan for using new technologies to increase the DSN's deep space communications capabilities to accommodate a growing exploration fleet while maximizing the utility of the existing DSN antennas. The first major goal of this implementation will be the addition of Ka-band reception capability on all of the DSN's 34-meter beam wave-guide antennas. An implementation plan was developed in FY 1999 that has successfully passed a preliminary definition and cost review, and has moved on to prototyping activities for certain key technologies. One of these technologies currently under test is a single microwave feed horn and associated cryogenic low-noise amplifiers that can receive both X-band (8 GHz) and Ka-band (32 GHz) simultaneously. The other significant effort undertaken as part of the telecommunications roadmap is the completion of the DSS-26 34-meter antenna at Goldstone. The electronics for this antenna are being developed and installed to make this antenna operational in FY 2001.

Additional upgrades of the unique 70 meter antennas were made to avoid obsolescence issues and develop an improved transmit capability. The 70 meter X-band Uplink task will implement a higher power transmit capability to better communicate with spacecraft in the outer solar system. The 34-meter antenna-arraying task is also nearing completion. This task has already demonstrated the improved performance achievable through the use of an array of multiple antennas and will be operational in early FY 2000.

Ground Network Upgrades

The Ground Network consists of the Merritt Island Launch Area (MILA) station and the Ponce de Leon (PDL) inlet annex in support of Shuttle launch and landing activities. The aging 9-meter hydraulic antennas at MILA are being replaced with electric drive systems, capable of functioning without an operator. Efforts in support of this initiative will begin in FY 2000 and be completed in FY 2001. Infusion of technology developed in support of receiver, exciter, and ranging subsystems will be introduced in a phased manner to replace aging subsystems at MILA and Ponce de Leon. This effort will continue throughout FY 2000 with completion expected in FY 2001.

The Wallops Flight Facility (WFF) completed the installation of the 11-meter telemetry antenna systems at the Poker Flat Research Range near Fairbanks, Alaska and at Svalbard, Norway in preparation for support of the QuikSCAT and Landsat-7 missions in FY 1999. Ground station and network integration and certification testing was completed in FY 1999. The systems are scheduled to be officially transitioned to CSOC for operations, maintenance, logistics, and sustaining engineering in FY 2000. NASA is planning for the future of the McMurdo Ground Station (MGS) in Antarctica. The drivers for this station are the need to provide for predictable performance of MGS in support of Launch and Early Orbit Operations, to provide for supplemental Earth Observing System (EOS) Polar Ground Network (EPGN) support, and to pursue a mutually beneficial relationship with the U. S. Air Force with regard to improved service and cost sharing. Concept definition, project plans, and approval to proceed were granted in FY 1999. Upcoming plans for MGS in FY 2000 include the implementation of a Joint Operations Center (JOC) with the U. S. Air Force and subsystem upgrades in support of the EOS missions.

Work will continue on the replacement of the Wallops Range Data Acquisition and Computational System; this system is a range safety tool and is obsolete and expensive to maintain. Work on the 11-meter antenna system enhancements required to support the Advanced Earth Orbiting Satellite (ADEOS) II mission will be completed in FY 2001.

The Ka-Band Ground Terminal Development activity will begin in FY 2000. This effort will seek to demonstrate the commercial viability of providing high rate ground data acquisition in the Ka-Band area. This activity will include participation by members from various NASA centers and commercial vendors. The successful demonstration of this capability is scheduled for late FY 2001. Capabilities to be demonstrated are far beyond what is in operation today. Success will allow NASA and its commercial partners to take advantage of the new frequency allocations for space and earth science and to alleviate issues regarding radio frequency spectrum interference that exist today.

Mission Control and Data Processing Upgrades

The Mission Control and Data Processing area has pursued proactive measures to consolidate functions, close marginal facilities, and reduce overall contractor workforce to reflect the Agency's goals. Examples include the transition of both the SAMPEX and FAST MOC operations to ITOS workstation systems and the outsourcing of FAST mission operations to the UCB, the completion of the ISTP Reengineering consolidation of Wind and Polar operations with SOHO to be completed in FY 2000, and the use of automation to monitor routine spacecraft health and safety functions to enable smaller flight operations teams and reduced operations schedules (RXTE, CGRO, Landsat-7, etc.).

Transfer of data systems technologies to flight project use occurred in the areas of software reuse, expert system monitoring and command of spacecraft functions, and packet data processing systems. Software reuse, expert systems, workstation environments, and object-oriented language applications continued. The Mission Control and Data Systems upgrades areas will continue to integrate modern technology into mission operations support systems through the use of systems like the GenSAA for automation, software-based telemetry front-end processing systems and the Mission Operations Planning and Scheduling System, case-based and model-based reasoning tools, and commercial orbit planning systems.

Significant development, test, and pre-launch support associated with the MIDEX and SMEX missions are part of the Mission Control and Data Systems activity. Emphasis upon commercial products, artificial intelligence applications and advanced graphical displays will be continued in FY 2000 for application in MIDEX and future SMEX missions. Evolution of systems to a single integrated mission control, command management, flight dynamics, and first-level science processing system will continue. The Flight Dynamics Facility (FDF) operations concept to perform routine operations as integral functions within mission control centers will also continue into FY 2000. New flight dynamics technology development and infusion for autonomous space and/or ground spacecraft navigation and control will be major efforts.

Preparations for the HST Third Servicing Mission in FY 2000 will continue, including the delivery of the Vision 2000 ground system, delivery of the new flight control computer flight software, and the payload computer ACS support system. Development efforts will continue in preparation for the MIDEX MAP mission that is scheduled to launch in FY 2001.

The Mission Operations and Data Systems upgrades efforts will continue to focus efforts on operations automation beyond the RXTE Automated Mission Operations System (AMOS), the CGRO Reduced Operations by Optimizing Tasks and Technologies (ROBOTT), and the automation provided for TRACE to promote single shift staffing for operations. Mission Control and Data Systems will actively lead and participate in establishing new architecture directions and rapid prototyping, exploring system autonomy concepts, and use of commercial-off-the-shelf products.

Mission Control and Data Systems upgrades area will continue the lead in scoping and prototyping innovative architectures such as: the use of Transmission Control Protocol/Internet Protocol or Space Communications Protocol Standards for ground and flight communications; the use of knowledge-based control languages; ground and space autonomy; and active endorsement and collaboration in formulating a Space Objects technology for adoption and implementation of plug-and-play components for mission operations. Exploration of the promise of advanced communications technologies will continue throughout this period.

Development for Triana and MAP will be completed in FY 2001; developments will continue for the MIDEX and SMEX series as well as for the HST Servicing Mission 3B. Development efforts on Triana, MAP, EO-1, and similar missions will realize benefits from modern technology, commercial products, and more cost-effective processes (for example, a single system to perform spacecraft integration and test and mission operations; skunkworks development teams; concurrent engineering). The flight dynamics work will continue to be provided in the areas of ground support system development, analysis, and automation tools.

BASIS OF FY 2001 FUNDING REQUIREMENT

TRACKING AND DATA RELAY SATELLITE REPLENISHMENT PROJECT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Spacecraft Development	[66,700]	[17,700]	14,500
Launch Services	[30,200]	[14,000]	40,500
Total	[96,900]	[31,700]	55,000

PROGRAM GOALS

The objective of the TDRS Replenishment Project (TDRS H, I, J Spacecraft) is to provide three spacecraft to continue Space Network tracking, data, voice, and video services to NASA scientific satellites, the Shuttle, International Space Station, and to other NASA customers. The spacecraft are replacements to the current constellation of geosynchronous TDRS satellites as they begin to exceed their lifetimes. The functional and technical performance requirements for the satellites will be virtually identical to those of the current satellites except for improved multiple access and S-band single access performance, addition of Ka-band, and spacecraft collocation. The three spacecraft will be placed in orbit by expendable launch vehicles (ELV).

STRATEGY FOR ACHIEVING GOALS

The Goddard Space Flight Center manages the development of the TDRS Replenishment Project, and the systems modification of the ground facilities and equipment as necessary to sustain network operations for current and future missions. The three TDRS spacecraft, procured under a fixed-price contract, were awarded to the Hughes Space and Communications Company in 1995. The first spacecraft's launch readiness is scheduled for June 2000. Lockheed Martin Corporation is the prime contractor for launch services for the TDRS Replenishment Spacecraft.

SCHEDULE AND OUTPUTS

Launch TDRS-I Plan: 2002	Launch within five years of contract award will be performed, ensuring the continuity of TDRSS services to user space flight systems. This will be the second of three TDRS Replenishment Spacecraft.

ACCOMPLISHMENTS AND PLANS

In FY 2001, the TDRS-I spacecraft will continue ground storage. The TDRS J Spacecraft will complete final functional testing. TDRS J spacecraft will undergo a pre-storage review and the contractual option to store the spacecraft will be exercised.

BASIS OF FY 2001 FUNDING REQUIREMENT

TECHNOLOGY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Advanced Communications	[22,800]	[21,300]	14,000
Space Internet	[4,300]	[4,100]	5,100
Virtual Space Presence	[5,900]	[5,300]	6,400
Autonomous Mission Operations	[5,700]	[5,400]	7,700
Advanced Guidance, Navigation, and Control	[4,700]	[4,100]	5,200
Total	[43,400]	[40,200]	38,400

PROGRAM GOALS

The objective of the Communications Technology Project (CTP) is to identify, develop, integrate, validate, and transfer/infuse advanced technologies that will increase the performance, provide new capabilities, and reduce the costs of providing data and mission services to the Space Operations customers. Additionally, the CTP infuses new capabilities into commercial practice for the benefit of both NASA and the Nation. Essentially all tasks serve to improve and/or reduce the cost of space operation services, or provide the technology advancement to allow the introduction of new services to the Integrated Operations Architecture.

STRATEGY FOR ACHIEVING GOALS

Advanced Communication

The focus of this campaign is development of telecommunications technologies to increase data return and decrease costs for support of NASA's missions. The Advanced Communication Campaign is committed to the development of high performance communication technologies for use in future NASA spacecraft and the ground and space assets that support them. The new communication technologies and more efficient implementation schemes will enable or augment future NASA missions with enhanced, lower cost communication services and allow the scientific community to perform more and better research by providing them with access to greater overall communication system bandwidth. The mission of the Advanced Communication Campaign is to identify, develop, and infuse high performance communications technologies necessary to enable or enhance mission data services and to achieve seamless interoperability among NASA, commercial satellite, and terrestrial communications systems.

This campaign has focused work areas supporting the unique low signal levels of Deep Space, high data rates for Near Earth, and low size, weight, power, and cost components for all missions. Activities related to the development and validation of a wide variety of radio frequency (RF) and optical devices (antennas, receivers, transmitters, modems, and codes) are part of this campaign.

Space Internet

Supporting the IOA vision for transparent operations, the Space Internet Campaign seeks to provide users direct access to tools, payloads, and data. The mission of the Space Internet Campaign is to identify, develop, and infuse Internet and supporting communications infrastructure technologies necessary to achieve seamless interoperability between satellite and terrestrial networks. For Near Earth and near planetary missions, the Space Internet Campaign is committed to the extension of commercially available, terrestrial-based Internet technologies into future NASA spacecraft to enhance the capabilities for remote access and control of space-based assets. Deep Space missions will require new communications protocols and new relay telecommunications. The long round-trip light times, intermittent link availability, and extremely low signal-to-noise ratio (SNR) of deep space links demand carefully tailored protocols to achieve the kinds of high-level file transfer capabilities that we take for granted in today's terrestrial Internet. Within this campaign, we will develop new deep space protocols, test and validate them in protocol testbeds, and infuse them into new radios that provide high-level communication and navigation functionality in low-mass, power-efficient, highly interoperable systems. This campaign also includes activities related to development and validation of space qualifiable code, local area network (LAN), routing, and switching hardware and software.

Virtual Space Presence

As we gather more detailed science information in remote locations, and rely more heavily on robotic exploration and autonomous operations, we must shift how we plan, operate, and visualize these activities. These technologies provide improved science return through several means:

- Advanced data compression techniques and buffer management strategies,
- Advances in on-board processing including feature identification, data mining, fusion, and synthesis operations,
- Other onboard techniques that are coupled with intelligent approaches for information transfer prioritization and management of the limited return link resources.

Advanced tools for high fidelity 3-D visualization of planned and executed spacecraft activities, and the ability to remotely plan activities and display the results, enable distributed team operations and broad outreach by providing secure access to science and mission information resources. This campaign also develops techniques for merging diverse but related data types, and technologies that will allow scientists, and thence the public, to fully visualize and appreciate the value of the returned science products.

Autonomous Mission Operations

This campaign will enable the planning, design, development, and operation of missions with challenging observational or exploration scenarios. These include autonomous decision-making and control for complex navigation and guidance scenarios, collaborative robotic exploration of remote bodies or terrain, autonomous observation planning and optimization of information return, and hazard avoidance and autonomous maintenance of spacecraft operational safety. Model-based system design and operation, goal-oriented planning, and related advanced testing techniques for autonomous systems are essential elements of these approaches. System automation to increase information handling and effective science return, automate system responsiveness to operational activities and spacecraft driven service requests, and automated detection and response to unplanned events are elements of this campaign.

Advanced Guidance, Navigation and Control (GN&C)

Enabling the planning, design, development, and operation of missions with challenging navigation scenarios is the Advanced GN&C Campaign. Scenarios include autonomous navigation and guidance for entry, descent, precision landing, and rendezvous & docking, autonomous formation flying and constellation operations, and operation in complex gravitational fields such as small body or Europa orbits, and Libration points. Many of these mission scenarios require highly responsive guidance approaches with control loops closed on the spacecraft rather than between spacecraft and ground. Autonomous maneuver decision making, planning, and execution techniques are being extended to enable distributed networks of individual vehicles to interact with one another and act collaboratively as a single functional unit. The activities in this campaign include the techniques and subsystems to enable the relative positions and orientations of vehicles to be determined; formation flying control architectures, strategies, and management approaches; inter-spacecraft communication techniques for constellation coordination; and assess ground/flight operations concepts, trades, and accommodation requirements. Global positioning system (GPS) technologies that have been utilized for applications at the Earth are being evaluated and extended to support autonomous navigation for non-low earth orbit (LEO) missions.

SCHEDULE AND OUTPUTS

Optical Communications Technology Laboratory (OCTL) First Light Plan: 1st Qtr FY 2001	OCTL development completed and installed at Table Mountain. Performance Validation initiated.
Autonomous formation flyer unit complete Plan: 4th Qtr FY 2001	Iteration of sensor technology hardware and software system required for multiple spacecraft flying in formation.
Disseminate ACTS experiment results and complete data and record archiving Plan: 4th Qtr FY 2001	Overall experiment results will be catalogued and made available through the ACTS Web Page (http://acts.grc.nasa.gov).

Common Planning and Scheduling System (COMPASS) design review for distributed constellation planning Plan: 4th Qtr FY 2001	COMPASS capability extended to provide flight planning and scheduling in addition to science planning.

ACCOMPLISHMENTS AND PLANS

A low power transceiver is being developed for near earth missions which will allow the unit to process up to 12 channels allowing simultaneous Tracking and Data Relay Satellite System (TDRSS) and Global Positioning System (GPS) signal reception. Development began in FY 1999 with implementation of a digital matched filter/correlator in an FPGA as a first step, prior to a lower power implementation. In FY 2000, the FPGA-based transceiver development will be focused on a prototype capable of use for ground-based demonstrations as well as a possible short duration Shuttle flight targeted for FY 2001.

The Scientist's Expert Assistant (SEA) will be used as the front end of a planning tool. The SEA includes a Visual Target Tuner which allows Principle Investigator's to visually specify what they want to observe. This will feed directly into a planning tool to schedule and execute the specified observation. In this way the SEA will be able to support other observatories including HST, Chandra, GRO and XTE. SEA will be developing a simulation feedback loop, to improve the accuracy of observation specifications. (The PI will request an observation, the SEA will simulate the results, the PI will assess the simulation and adjust his/her request, and then the observation will be executed. As a result, fewer mistakes will be made and resources will be used more efficiently.) Other observatories such as HST, Chandra, GRO and XTE can also use this enhancement.

NASA will continue propagation data measurement and analysis at Ka-Band begun under the ACTS project, and extend the propagation models to include V-Band frequency data collection and analysis. The unique ACTS propagation terminals will be modified to include V-band capability, and will be used to obtain the propagation data required for model validation. The end of FY 2000 will complete modification of two terminals. The French Ministry of Defense is providing the Ka-Band and V-Band satellite beacons at no cost to NASA. However, the beacons are only measurable in the U.S. from Puerto Rico. NASA's propagation measurement activities will rely on the successful operation of the French STENTOR satellite, scheduled for launch in the first quarter of FY 2001. Ka-band and V-band propagation data will be collected and analyzed beginning in FY 2001.

Key technologies needed to enable utilization of Ka-band communications on future deep space missions will continue. A new Ka-band reflector array membrane will be designed, fabricated and integrated with the 3-m inflatable antenna structure developed last year. Additionally, mechanical mounting and stability analyses will be completed to assess the expected performance of such antennas under space flight conditions. A contract will be let for the development of a 30 Watt (24 Watt at end-of-life) output, Ka-band Traveling Wave Tube Amplifier which is more than 40% efficient. Additionally, a miniature

Ka-band Opto-electronic oscillator (OEO) with 1 Hz phase noise sidebands 32 dB below the carrier will be demonstrated. The OEO uses fiber delay line technology to permit the direct generation of a Ka-band signal source. Previous techniques generated lower-frequency signals and then multiplied the frequency (and the phase noise distortions) up to the Ka-band carrier frequency. Low 1 Hz phase noise is necessary for weak signal detection and synchronization of Ka-band deep space communication signals. These developments will provide the remaining major ingredients (complementing the STM technology that was infused into follow-on development programs last year) needed to enable high capacity Ka-band communications on future deep space missions

Development of the Optical Communications Telescope Laboratory (OCTL) will continue with the completion of the building modifications for the OCTL, and the issuance of the OCTL telescope contract. The OCTL facility will be used to demonstrate and validate optical communications techniques, components and systems-level demonstrations links for applications to NASA future high capacity near Earth and deep space communications needs. In FY 2001, we will complete the development of the OCTL Telescope, install it in the telescope facility completed on Table Mountain, California begin "first-light" validations of the telescope performance, and begin preparations for systems-level demonstrations of optical communications and component technology validations.

Work is continuing in using Global Positioning System Derived Navigation in planetary rendezvous and formation flying environments. Several flight programs are assessing the Autonomous formation Flyer (AFF) sensor. This work area continues to develop a general AFF sensor with multi-mission capability.

Technology verification experiments over the ACTS will continue through to the end of spacecraft operations in June 2000. The technology verification experiments are coordinated by GRC and are being conducted by a team of investigators to study various propagation and link performance at Ka-band, to characterize system availability, and to perform statistical system analysis of the ACTS technologies. All spacecraft data received from ACTS technology verification experiments will be archived for future use. Final data analysis of the spacecraft data and experiments will be completed in early FY 2001. The overall experiments program results will be catalogued and made as accessible as possible through the ACTS Web page (http://acts.grc.nasa.gov). Completion of all data archiving and results dissemination will occur by September 2001.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Education	71,600	85,039	54,100	SAT 7.1-1
Minority research and education	66,900	53,771	45,900	SAT 7.2-1
Total	138,500	138,810	100,000	

SCIENCE AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS **EDUCATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Student support programs	8,600	10,200	7,300	SAT 7.1-6
Teacher/faculty preparation and enhancement programs	12,800	8,700	9,100	SAT 7.1-9
Support for systemic improvement of education	35,300	35,800	30,400	SAT 7.1-11
Educational technology	14,200	28,839	5,800	SAT 7.1-16
Evaluation	700	1,500	1,500	SAT 7.1-19
Total	71,600	85,039	54,100	
Enterprise Program Funding			[7,500]	
Total Program Funding	71,600	85,039	61,600	
Distribution of Program Amount by Installation				
Johnson Space Center	1,300	1,000	1,000	
Kennedy Space Center	600	600	600	
Marshall Space Flight Center	1,600	2,000	2,000	
Stennis Space Center	1,000	1,000	1,000	
Ames Research Center	3,200	2,700	2,700	
Dryden Flight Research Center	400	500	500	
Glenn Research Center	2,100	1,000	1,000	
Langley Research Center	1,300	1,200	1,200	
Goddard Space Flight Center	50,900	62,539	31,600	
Jet Propulsion Laboratory	400	500	500	
Headquarters	8,800	12,000	12,000	
Total	71,600	85,039	54,100	

PROGRAM GOALS

NASA's direction for education is set forth in the NASA Strategic Plan as one of the Agency's five contributions to the Nation's science and technology goals and priorities:

> ***Educational Excellence.*** *We involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds.*

This contribution is accomplished through implementation of a full range of NASA education programs and activities that contribute to the various efforts and activities of those involved with and in the education community, and benefit the participants as well as advance the mission of the Agency. Progress towards this goal is measured in two ways:

- **Excellence**: NASA seeks to be judged by its customer, the education community, as providing excellent and valuable educational programs and services. Therefore we will attempt to maintain an "Excellence" rating ranging between 4.3 and 5.0 (on a 5.0 scale) as rated by our customers.
- **Involvement**: NASA strives to involve the educational community in our endeavors. Therefore, at the proposed funding level, we seek to maintain a current level of participant involvement of approximately 3 million with the education community, including teachers, faculty, and students.

STRATEGY FOR ACHIEVING GOALS

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the NASA mission holds for students and educators. The unique character of NASA's exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into education endeavors which support local, state, and national educational priorities. In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for a diverse group of educators and students to experience first hand involvement with NASA's scientists and engineers, facilities, and research and development activities. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of NASA's activities, and return to the classroom with enhanced knowledge and skills to share with the education community.

NASA Implementation Plan for Education

The NASA Implementation Plan for Education provides general guidance for the implementation and continual improvement of the NASA Education Program for fiscal years 1999-2003. Specifically, the plan

- Identifies three leadership strategies to improve and guide the NASA Education Program: (1) contribute to educational excellence; (2) develop alliances; and (3) involve the education community.
- Outlines the education agenda for the next five years through seven improvement initiatives: (1) focus and coordinate state-based efforts; (2) enhance instructional products and dissemination; (3) improve education program integration and coordination; (4) facilitate NASA research in the higher education community; (5) support preservice education; (6) target informal education; and (7) implement NASA's comprehensive data collection and evaluation system.
- Delineates the operating principles integral to the conduct of all NASA education activities: customer focus; collaboration; diversity; and evaluation.
- Defines the NASA Education Program and Evaluation Framework, the basis from which our agency-wide and center-based programs are organized, implemented, and evaluated.
- Describes the roles and responsibilities of the various organizational entities that carry out the NASA Education Program.

This plan provides guidance for agency-wide education programs as well as programs and activities carried out by the NASA Enterprise Offices, the Office of Equal Opportunity Programs, and the NASA field centers.

SCHEDULE & OUTPUTS

The NASA Education Program and Evaluation Framework was established to serve as a model to guide the implementation and evaluation of NASA's Education Program. During FY 1999, NASA has further refined and implemented the framework and the evaluation system that was pilot tested in FY 1996. Three levels of performance measures have been developed. At the top level, all programs have measures that relate to the Program's primary metrics: excellence and involvement. Data showing progress towards these metrics are provided below. At the second level, each implementation approach has specific measures that all programs in that particular category are measured against such as career goals, program value, curriculum integration/use, standards awareness and utilization, overall quality, partnerships/alliances, service quality, and usage. At the third level, each program, in addition to the applicable second level measures, has program specific measures that show progress as well as participant written feedback that provides qualitative evaluation data.

ACCOMPLISHMENTS AND PROPOSED RESULTS

FY 99 Achievements

In FY 1999, the NASA evaluation system was able to collect data on most of the agency wide education programs, and many center-specific programs and activities. The data summary below is a roll up of top level measures that relate to the Education Program's

two metrics - - excellence and involvement. The data is for FY 1999, as of 12/15/99. This is still considered preliminary as data roll up continues through January 2000.

Excellence

Progress towards this metric is measured by a quality rating by the educational customer of NASA's performance. The following data were collected:

Participant ratings of excellence (score: 5=excellent to 1=very poor; total participants reporting: 30,071 participants responding; not all participants are asked all 4 questions; 62-82 programs reporting)

- 4.70 Recommend to others
- 4.69 Rate staff
- 4.58 Expect to apply what was learned
- 4.68 Valuable experience
- Overall average for excellence: 4.66

Based on this information, the NASA Education Program is meeting its metric of excellence, as defined by the satisfaction expressed by our customers. As the FY 1999 data collection is completed, it is anticipated that additional participants will report, but we do not expect the ratings to change significantly.

Involvement

Progress towards this metric is measured in two ways: (1) total number of participants, including students/teachers/faculty/Administrators, etc., involved in NASA education programs; and (2) number of partnerships/collaborations. The following data were collected:

- Total in-person involvement in NASA Education activities: 3,702,645.
- Total involvement in NASA Education activities: 37,360,885 (189 programs reporting)
    - In-person: 3,702,645; electronic: 9,020,044; general public: 24,638,196
    - 42% students; 6% teachers/faculty; 10% Administrators, Civic, Parents, etc. ; 51% other
    - Students: 1,557,561; 33% K-4; 42% 5-8; 24% 9-12; 3% under grad; 0.5% grad
- K-12 Teachers and Higher Education Faculty: 228,003. K-12 Teachers: 201,074; 35% K-4; 39% 5-8; 26% 9-12; Higher Educators/faculty:= 26,929: 6% Community College; 11% Undergraduate Faculty; 82% Graduate Faculty. Total Teachers and Faculty: 228,003. The K-12 numbers represent teachers teaching each grade group, not the total number of teachers – one teacher can teacher more than one grade so these numbers can't "add up." These percentages are calculated as a ratio based on the 201,074. The breakdown of K-12 teachers is not used to come up with the total – only the total number of K-12 teachers given to us by the program managers, and in some cases, they do not provide any grade at all. We thus have 201,074 K-12 teacher people.

- However, this is not the case in calculating the percentages for higher education teachers which is 228,003. 27% K-4; 30% 5-8; 20% 9-12; 1% community college; 1% undergraduate; 10%
- Types of K-12 schools represented (5,294 participants reporting)
- 30% urban; 37% suburban; 33% rural

• NASA programs and external alliances

- 6,096 instances of alliances
- higher education institutions; industry; contractors, other NASA facilities; Educator Resource Center Network; non-profits; local community; school districts

It is clear from the number above the NASA Education Program is meeting the metric of involving 3 million participants in our programs and we anticipate continuing to do so in FY 2000.

BASIS OF FY 2001 FUNDING REQUIREMENT

STUDENT SUPPORT PROGRAMS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Elementary and secondary	2,200	3,800	3,800
Higher education	6,400	6,400	3,500
Total	8,600	10,200	7,300

PROGRAM GOALS

The goal of the Student Support Program is to use the NASA mission, facilities, human resources, and programs to provide information, experiences, and research opportunities for students at all levels to support the enhancement of knowledge and skills in the areas of science, mathematics, engineering, and technology.

STRATEGY FOR ACHIEVING GOALS

Student support activities: (1) provide NASA mission experiences and information that are designed to promote students' interest and achievement in science, mathematics, technology, and geography; (2) provide exposure to NASA research and/or research experiences and activities to promote science, mathematics, technology, engineering, and geography career awareness; (3) provide support to the science and technology workforce pipeline by including greater participation of individuals who are under represented in science, mathematics, technology, and geography in NASA student programs; and (4) increase the number of NASA student support opportunities through partnerships and interagency cooperation and collaboration.

Activities such as the NASA Student Involvement Program (NSIP) and the Shuttle Amateur Radio Experiment (SAREX) provide general exposure to NASA's mission and stimulate interest in mathematics, science, and technology subject matter. Additional activities such as the Summer High School Apprenticeship Research Program (SHARP and SHARP-PLUS), demonstrate the applications of mathematics, science and technology by providing research experiences for students who traditionally have not been represented in mathematics, science and engineering fields. At the higher education level, activities such as the Graduate Student Researchers Program (GSRP) provide support to train students in NASA-related disciplines at both the master's and doctoral levels.

SCHEDULE & OUTPUTS

In FY 99, 1,533,469 students participated in NASA education activities. Elementary/secondary students comprised almost 97% of that number, in a variety of programs, projects, and activities.

In addition to collecting "excellence" and "involvement" data, second level metrics are also collected for student support programs. These include data on applicant/award ratio; gender, ethnicity, demographics; college major; career goals; interest change; and program value.

For example, 506 students participated in the Summer High School Apprentice Research Program (SHARP/SHARP Plus). This program involves under represented minority high school students in intensive research apprenticeships with NASA, industry, and university scientists and engineers. SHARP students live within commuting distance of a NASA installation; SHARP PLUS students have residential research experiences at a participating Historically Black College or University or a Predominately Minority Institution. The goal of both programs is to involve students from groups traditionally under represented in science, mathematics, engineering, and technology in research environment. The program is very competitive as only 22% of those who apply are accepted into the program. Seventy-four percent of these students are juniors in high school when they enter the program; 52% of the participants are female; approximately 32% are African American and 20% are Hispanic. Participants rate the program as being a valuable experience (4.8) and would recommend to others (4.7) (Score: 5=excellent; 1=very poor). At the conclusion of their experience, 50% indicated a career goal of engineer (level of interest in this discipline area changed for a 3.5 to 4.2 over the course of the experience).

ACCOMPLISHMENTS AND PROPOSED RESULTS

General plans for Student Support Programs in FY 2000 and FY 2001 include the development and maintenance of electronically disseminated communication of NASA-sponsored student opportunities and career information to our customers, and better coordination of student program efforts across the NASA system to ensure the progression of students from one program to another.

In FY 2000, SHARP and SHARP Plus, will be combined under one procurement vehicle, which will create greater efficiencies in the management of these programs. However, both the residential and center based components will be maintained.

Other agency-wide student programs include the NASA Student Involvement Program, Shuttle Amateur Radio Experiment, and the Graduate Student Researchers Program. The NASA Student Involvement Program continues to promote literacy in science, mathematics, and technology among students in grades 3-12. More than 3,211 students continued to participate in the program. The program insures linkages with the NASA Enterprises and provides standards-based, hands-on, inquiry-oriented learning experiences, including an opportunity for high school students to fly experiments on the space shuttle or a sounding rocket.

The Shuttle Amateur Radio Experiment continued in FY 1999 to provide students the opportunity to participate directly in the Shuttle program by communicating directly with astronauts via amateur radio. Again, more than 10,000 students, administrators, teachers, parents, community members, ham radio operators and the media, participated in this overall program. Also, other

schools planned to listen to the audios and do distance learning-type projects. In FY 2000/FY 2001, work will continue to integrate SAREX on the International Space Station.

The Graduate Student Researchers Program continued in FY 1999 to provided graduate fellowships to U.S. citizens conducting thesis research in NASA related areas. Approximately 300 students were supported full time, and a similar number is expected in FY 2000.

In FY 2000, development will begin on a coordinated, agency-wide, undergraduate internship program. This program will be developed as a student research opportunity, designed to increase diversity in the pipeline for NASA, and to fill a gap in programs at the undergraduate level. Plans are to implement the program in FY 2001.

In FY 2001, Student Programs will be maintained at the same funding and general participation levels as in FY 2000. However, $2.5 M in funding for the GSRP and the internship program will be provided by the Enterprise Offices.

BASIS OF FY 2001 FUNDING REQUIREMENT

TEACHER/FACULTY PREPARATION AND ENHANCEMENT PROGRAMS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Elementary and secondary	4,200	3,700	3,700
Higher education	8,600	5,000	5,400
Total	12,800	8,700	9,100

PROGRAM GOALS

The goal of the Teacher/Faculty Preparation and Enhancement Programs is to use the NASA mission, facilities, human resources, and programs to provide exposure and experiences to educators and faculty, to support the enhancement of knowledge and skills, and to provide access to NASA information in science, mathematics, technology, engineering, and geography.

STRATEGY FOR ACHIEVING GOALS

At the elementary and secondary level, preparation and enhancement activities are designed to (1) provide NASA mission-based programs that introduce the application of science, mathematics, geography, engineering, and technology for use in student learning activities; (2) provide educators with a wider range of alternatives using scientific inquiry, based on the NASA mission; (3) encourage a "multiplier" effect to expand the benefits of the in service program beyond participants to include additional educators; (4) provide access to and promote utilization of NASA related materials and information resources; (5) increase the participation of under served and under utilized individuals and groups; and (6) facilitate collaborations between the faculty of teacher preparation departments and the faculty of scientific and technical departments to develop innovative approaches to teacher preparation. Pre-service programs such as Project NOVA, and in-service programs such as the NASA Education Workshops (NEW) and the Urban Community Enrichment Program (UCEP) are designed to enhance and improve the teaching of mathematics, science, and technology by demonstrating their applications in aeronautics and space through workshops around the country. The Teaching From Space Program continues to provide instructional products that help support these preparation and enhancement workshops.

At the higher education level, activities are designed to enhance faculty research skills and content knowledge; balance participation so that a cross-section of colleges and universities is represented (i.e., community colleges, four year institutions, institutions that serve significant numbers of under represented groups, under funded institutions); and provide opportunities for curriculum expansion/revision that aligns with the mission needs of NASA and universities. Activities such as the Summer Faculty Fellowship Program (SFFP) provide research experiences for faculty at NASA field centers to further their professional knowledge in the engineering and science disciplines, and to ultimately enhance the undergraduate/graduate curriculum.

SCHEDULE & OUTPUTS

In FY 1999, 488,744 educators and faculty participated in NASA education activities. K-12 educators comprised approximately 98% of that number. For example, 376 453 educators participated in the NASA Education Workshops (NEW). These workshops, held at NASA centers during the summer, provide an opportunity for practicing teachers to update their background and skills in science, mathematics, and technology. Twenty-two percent of participants represent suburban schools, 27% urban, and 37 rural. On a rating scale of 5 (5-excellent; 1=very poor), participants rated "expected to apply what learned" at 4.8 and "valuable experience" at 4.8.

ACCOMPLISHMENTS AND PROPOSED RESULTS

General plans for teacher/faculty preparation/enhancement programs in FY 2000 and FY 2001 include plans to model inquiry-based science investigations or meaningful mathematics problem solving by engaging educators in the kinds of learning they are expected to practice with their students; expand follow-up and networking opportunities for the alumni of NASA's teacher enhancement programs; expand the scope of educator enhancement programs to include workshops at each center for institutions in their region that serve informal education and urban/rural systemic efforts; provide education experiences for educators in the effective application of educational technologies; and define and execute activities that target preservice education programs.

FY 1999 accomplishments for NEW are cited above. In FY 2000, partnerships between NASA and rural and urban education systems will continue to be strengthened through center based workshops. Other agency-wide programs included:

Teacher preparation programs such as Project NOVA disseminate nationally an undergraduate pre-service model based on standards and benchmarks for science, mathematics, and technology. NOVA links higher education faculty across several disciplines to create these models. To date, more than 81 colleges and universities have participated. The Urban Community Enrichment Program (UCEP) provides more than 1,572 urban teachers greater exposure to new NASA knowledge. The Teaching from Space Program continues to develop products that are incorporated into enhancement activities, providing tools that can be applied in the classroom and disseminated through the Educator Resource Center Network.

At the higher education level, the Summer Faculty Fellowship Program provides highly beneficial opportunities for U. S. citizen engineering and science faculty throughout the Nation to participate in NASA research. This program has contributed significantly to the improvement of both undergraduate and graduate education, and directly benefits NASA, universities, faculty, students and the Nation. Approximately 179 university faculty continue to be supported annually for ten weeks. This program provides opportunities for college and university faculty to come to NASA centers to work with NASA data and to enhance research and teaching capabilities. There are currently approximately 100 academic institutions participating, most of who had little previous contact with the agency.

The impact of slightly reduced funding levels in FY 2000 will be evidenced by slightly lower participation rates in workshops or in a reduced number of workshop opportunities at both the precollege and higher education levels. In FY 2001, the proposed increase in funding at the higher education level will result in increased opportunities for participation by faculty and higher stipend levels.

BASIS OF FY 2001 FUNDING REQUIREMENT

SUPPORT FOR SYSTEMIC IMPROVEMENT OF EDUCATION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Aerospace Education Services Program (AESP)	5,600	6,200	6,200
National Space Grant College and Fellowship Program	19,100	19,100	19,100
Experimental Program to Stimulate Competitive Research	10,000	10,000	4,600
Innovative Reform Initiatives	600	500	500
Total	35,300	35,800	30,400

PROGRAM GOALS

The goal of the Support for Systemic Improvement of Education Program is to use NASA's unique assets to support local, state, regional, and national science, mathematics, technology, engineering, and geography education change efforts through collaboration with internal and external stakeholders.

Systemic improvement encompasses the process whereby an entire system is re-engineered toward achieving a new goal. NASA is committed to supporting systemic initiatives in the areas of science and mathematics education, and its activities vary depending on the needs of the institution, school system, and/or state. Thus, the activities supported by programs included in this category seek to provide a range of support in response to the needs of the customer community.

STRATEGY FOR ACHIEVING GOALS

Systemic improvement activities are designed to: (1) coordinate planning among NASA education initiatives to ensure alignment with and support of standards-led systemic improvement initiatives of the states; (2) redirect existing education programs, and ensure new initiatives address state needs and tie unique education and economic development efforts; (3) support standards-based science, mathematics, technology, and geography education change by aligning NASA educational programs and products with the national/state standards; and (4) expand interactions with external stakeholders in the systemic improvement of education change.

A major program at the elementary and secondary education level is the Aerospace Education Services Program (AESP). The AESP's primary focus is teacher enhancement with emphasis on and support for local, state, regional and national mathematics, science, and technology education efforts through collaboration of internal and external stakeholders in high impact reform activities.

Systemic improvement activities at the higher education level use partnerships, linkages, and collaborations to provide activities and experiences designed to enhance research and educational capabilities, and enhance the collaborative capabilities of a diverse set of

academic institutions. Programs such as Space Grant and EPSCoR play a major role in NASA's contribution toward the Nation's systemic educational reform efforts.

The Space Grant Program, authorized by Congress in 1987, increases the understanding, assessment, development, and use of aeronautics and space resources. All 50 states, Puerto Rico, and the District of Columbia have Space Grant Consortium programs in which 729 affiliates participate. These consortia form a network of colleges and universities, industry, state/local governments, and nonprofit organizations with interests in aerospace research, training, and education.

The NASA EPSCoR Program provides seed funding that will enable eligible states to develop an academic research enterprise directed toward long-term, self-sustaining, nationally competitive capabilities in space science and applications, aeronautical research and technology, and space research and technology programs. This capability will, in turn, contribute to the state's economic viability.

Systemic improvement at both elementary and higher education levels is captured in NASA's Innovative Reform Initiatives program which is supportive of standards-based systemic improvement efforts, and focuses on science, mathematics and technology education. A means of supporting systemic improvement is through partnerships with professional education associations, national aerospace education associations, industries, other Federal agencies, and state and local groups. When NASA becomes a partner with these groups, its role may be one of leadership, being a participant, or acting as a facilitator to empower and enable wide reaching educational reform that is systemic in nature. An example of these partnerships is NASA's work with the National Alliance of State Science and Math Coalitions (NASSMC).

SCHEDULE & OUTPUTS

Performance in this area is measured in a variety of ways, including partnerships/alliances, supplemental funding, and standards. In FY 1999, NASA education instances of partnerships and collaborations activities documented 28,754 alliances with a variety of partners (note, a program may be involved in multiple alliances).

2% NASA Contractors; 3%Other Industry; 35% Local Community; 1 % Museums/Planetariums; 3% Non Profit; 1% Federal Agencies; 9% higher Education Institutions; 1% Other NASA; 34% K-12 Schools; 2% K-12 School Districts; 5% NASA HQ Program Office; 2% State Government; 2% Education Resource Centers. Partners included schools (K-12 and higher education), industry, and non-profit organizations.

More than $67M was secured in supplemental funding, of which 26% came from other Federal agencies, 6% from state agencies, 11% from Educational Organizations and Institutions; 11% from industry/business, and local organizations.

Other measures of performance are indicated below:

Aerospace Education Services Program

- 3,210 school visits; 4,625 student programs conducted; 145,085 students involved
- 1,706 teacher workshops conducted; 17,803 teachers participated
- Program was a valuable experience – 4.7 (on a scale of 5, 5=excellent; 1=very poor)
- Workshop content matched education objectives – 4.4
- Program demonstrated the interdisciplinary nature of NASA's research and development – 4.6

Space Grant (FY 1998 data)

- 52 University-based Consortia
- Space Grant involves 729 affiliates which include:
  - 518 colleges and universities
  - 52 business/industry
  - 34 State and local government agencies
  - 125 other affiliates (science museums, not for profits, etc.)
- $42.8M in matching funds (36% university; 22% other Federal, 10% industry; 23% other; 9% local/state government)
- 2,270 fellowships and scholarships (75% undergraduate; 22% under represented groups; 44% women)
- 932 education programs/projects/activities
- 373 public service programs/projects/activities

EPSCoR

Awards to twenty states:

- Alabama, Arkansas, Kentucky, Louisiana, Montana, Puerto Rico, Kansas, Nebraska, Oklahoma, South Carolina – original grants and prep grants
- Idaho, Kentucky, Louisiana, Maine, Mississippi, Nebraska, Nevada, South Dakota, Vermont, West Virginia – prep grants
- Participants: **(FY 1997 data)**
  - Institutions: 68
  - Research clusters: 47
  - Faculty: 244
  - Post doctoral fellowships: 38
  - Graduate students: 219
  - Undergraduates: 154
- $25.6M proposals funded
- 152 publications, refereed papers
- 2 patents; 5 patent applications; 1 invention disclosure

ACCOMPLISHMENTS AND PROPOSED RESULTS

General plans for Systemic Improvement activities in FY 1999 and FY 2000 include providing professional development on standards-based education initiatives to NASA's internal education community; reviewing existing NASA education initiatives to ensure their alignment with the vision and philosophy for state-based systemic reform; designing new programs or redesigning existing programs to ensure that all NASA efforts align with the science, mathematics, technology, and geography education standards and supporting the needs of those engaged in the implementation of standards-based education at the state and local levels; leveraging the use of NASA programs and resources by expanding NASA interactions and cooperation with all stakeholders involved in national and state systemic initiatives; and implementing a plan through the field centers that supports the needs of individual states.

The AESP specialists are directly involved in supporting state systemic improvement by providing technical linkages to NASA research and development and education programs and services. The AESP delivers educational services on a state-by-state basis. Each education specialist is assigned one or two states so they might become familiar with their states' science, mathematics, and technology education agenda and the education leaders within these states. This enables them to customize or tailor-make their teacher workshops to fit that particular state's framework. The funding in FY 2000 will continue operation of this program and allow the contract to be re-competed in FY 2000/FY 2001 timeframe.

In FY 1999 and FY 2000, funding for Space Grant was increased pursuant to Congressional direction. This funding increase provides for increased basic awards for all Space Grant consortia and supports the award of designation status to up to four additional state consortia. The FY 2001 budget maintains the FY 1999 and FY 2000 funding level for the Space Grant Program.

FY 1999 marked the sixth year of the NASA EPSCoR program with reduced funding for the original six awardees. These six states have been very successful in a short period of time, as evidenced by the metrics previously cited. In addition, four new states were chosen in the second round of awards in late FY 1996 (Kansas, Nebraska, Oklahoma, and South Carolina). They are completing their third year of work, and are expected to be as successful as the first group. Congressional direction in FY 1999 increased the funding for this program to $10.0 million. This enabled all eligible NASA EPSCoR states to receive planning grant funding for all twenty states. These awards will help these programs prepare for the next round of awards, scheduled for FY 2001.

NASA's Innovative Reform Initiatives program supports standards-based systemic improvement efforts and priorities, and focuses on science, mathematics, technology, and geography education. To prevent duplication and to strengthen the impact of systemic reform initiatives, NASA confers with other federal agencies and national organizations that are also working with educational systemic reform, including the National Science Foundation, U.S Department of Education, National Research Council, Council of Chief State School Officers, and professional education organizations such as the National Science Teachers Association, National Council for the Teaching of Mathematics, and the International Technology Education Association. Systemic reform initiatives are accomplished through partnerships with local, state, and national stakeholders including professional education associations, national aerospace education associations, industries, education agencies, and other interest groups. When NASA becomes a partner with these groups, its role varies between providing supportive leadership, being a complementary participant, or acting as a facilitator to empower and enable wide reaching educational reform that is systemic in nature. Examples of these partnerships are

the National Alliance of State Science and Math Coalitions (NASSMC), the Council of State Science Supervisors (CS3), the NASA Industry Education Initiative (NIEI). These partnerships are each mutually beneficial in creating systemic change by increasing the customer and support bases for both NASA and the partnering stakeholder. Similar opportunities will be explored in FY 2000 and FY 2001.

BASIS OF FY 2001 FUNDING REQUIREMENT

EDUCATIONAL TECHNOLOGY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Learning tools	1,700	3,800	3,800
Demonstrations	2,000	2,000	2,000
Learning Technologies Project	4,000	4,000	--
Franklin Institute	--	1,373	--
Jason XI	--	2,105	--
Sagan Discovery	--	915	--
Texas Learning	--	3,661	--
Space Science Museum	--	3,661	--
Ohio View	--	1,831	--
Completion of Science Learning Center in Kenai, AK	--	915	--
Lewis & Clark – Re-discover Web Tech	--	1,831	--
Univ. of San Diego for Sci & Ed Tech	--	458	--
City of Ontario CA for Sci & Ed Tech	--	458	--
Univ. of Maryland, Advanced Info Tech Center	2,000	--	--
Univ. of Redlands, Academic Infrastructure	3,500	1,831	--
Residential Aerospace Education Center	1,000	--	--
Total	14,200	28,839	5,800

PROGRAM GOALS

The goal of the Educational Technology program is to research and develop products and services that facilitate the application of technology to enhance the educational process for formal and informal education and lifelong learning.

STRATEGY FOR ACHIEVING GOALS

The Educational Technology program (1) produces technology-based teaching tools and strategies that are grounded in or derived from the NASA mission; (2) uses emerging technologies for, and applies existing technologies to, educational programs; (3) utilizes technology to facilitate communication within the educational community; (4) involves educators in NASA missions through innovative uses of technologies; and (5) conducts research into new teaching and learning practices that are made possible through NASA mission-derived technology.

The NASA Classroom of the Future (COTF) continues to be a major component of the educational technology program. The role of the COTF is to translate NASA technologies and research results into learning tools, demonstrations, and teacher enhancement programs that support standards-based education reform.

The NASA CONNECT program, an instructional television and web-based series, demonstrates work place math, science, and technology as collaborative processes. The teaching protocol is through reflective discussion, video engagement, dialogue notes, journal writing, and on-line engagement. The program is designed to raise student awareness of careers requiring math, science, and technology. This awareness will allow the students to overcome stereotyped beliefs regarding females and minorities in math, science and technology.

The Learning Technologies Project provides demonstration projects and on-line systems dedicated to bringing NASA science to teachers and students in the classroom using examples from NASA's unique missions. The goal of this program is to accelerate the implementation of a national information infrastructure through NASA science, engineering, and technology contributions and to facilitate the use of technologies within the K-12 education systems.

NASA Spacelink is an electronic resource specifically developed for the educational community. Spacelink is a "virtual library" in which electronic versions of NASA's educational products and hundreds of NASA World Wide Web links are arranged for educators. Educators can search this virtual library to find information regardless of its location within NASA.

SCHEDULE & OUTPUTS

Performance in this area is measured in a variety of ways, including overall quality, type/number of users; standards application; internet hits; data transferred; searchable pages; and unique IP addresses.

- **NASA CONNECT**: 75 PBS member affiliated stations; 5 state-wide educational networks; 11 district-wide educational stations; 147 community/cable access stations; Registrants: 73,000 educators, 4.7 million students; Channel One: 230,000 educators, 5 million students.

- **NASA Spacelink, and Learning Technologies Project:** 123,247,600 internet hits; 18,865 GB data transferred; 7,686,381 unique IP addresses.

- **Classroom of the Future** Research and Development: Two major instructional CD-ROMS, BioBlast and Astronomy Village, were developed and dissemination begun; one web-based Earth science curriculum supplement; one on-line course for Earth science teachers; 25,000 materials disseminated; 15,000 students and 7,000 teachers served.

ACCOMPLISHMENTS AND PROPOSED RESULTS

General plans for this program area include providing technology training and support for the persons involved in the operation of the Educator Resource Center Network and the Space Grant program; implementation of a coordinated electronic dissemination system that ensures that all NASA education activities and products are available through appropriate networking technologies; demonstrate NASA's educational technology resources at professional development conferences; develop innovative learning tools and technologies that are integrated with curriculum support and teacher enhancement activities ; develop, implement, and evaluate distance education and virtual mentoring projects; and support distribution of excess NASA equipment to schools and institutions of higher education.

Educational Technology activities support the development of high quality, affordable learning tools and environments (e.g., CD-ROM databases, DVD-ROM, live or taped video, computer software, multimedia systems, virtual reality) and supplementary instructional materials. These tools use existing technology as well as emerging technologies to facilitate education programs. Demonstrations of innovative, efficient, and effective technology and networking applications are also supported. Classroom of the Future continues to be NASA's primary educational technology research and development site.

NASA's Educational Technology program includes the center-based components of the Learning Technologies Project (LTP). One of the goals of this program is to demonstrate how newly emerging communication technologies can be used to bring NASA's science and engineering data to schools and the public. The ten center-based projects have made extensive amounts of earth, space, and aeronautics information available on the Internet in educational formats. Through this program, collaborations are maintained with and support provided to schools across the country. In FY 2000 LTP will initiate a follow-on grant program funding the use of information technology in educational outreach efforts. In FY 2001, funding for this program will be provided by the Enterprise offices.

Educational Technology activities in FY 1999 included funding for the following activities directed by Congress in the Conference Report accompanying the VA-HUD-Independent Agencies Appropriation Act: the University of Maryland Advanced Information Technology Center, University of Redlands Academic Infrastructure, and Residential Aerospace Education Center at the Glenn Research Center.

Educational Technology activities in FY 2000 include funding for the following activities directed by Congress in the Conference Report accompanying the VA-HUD-Independent Agencies Appropriation Act: the Franklin Institute, Jason XI, Sagan Discovery, Texas Learning, Space Science Museum, Ohio View, Completion of Science Learning Center in Kenai, AK, Lewis & Clark , University of San Diego for Science & Education Center, City of Ontario California for Science & Education Center, University of Maryland Advanced Information Technology Center, University of Redlands Academic Infrastructure, and Residential Aerospace Education Center at the Glenn Research Center.

In FY 2001, funding for Educational Technology programs reduces, however, the funding for the LTP will be provided by the Enterprise Offices.

BASIS OF FY 2001 FUNDING REQUIREMENT

EVALUATION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Evaluation	700	1,500	1,500

PROGRAM GOALS

The goal of the evaluation program is: to provide a substantive accounting and evaluation of the performance of NASA's educational program, with its associated projects and activities, in the implementation of its goals by developing and maintaining a systematic strategy for collecting, aggregating, and reporting evaluation indicator data.

STRATEGY FOR ACHIEVING GOALS

NASA has undertaken a comprehensive effort to evaluate its education programs in order to demonstrate the accomplishment of achievable and measurable goals and objectives. A set of standard, agency wide indicators, metrics, and evaluation instruments has been developed for agency wide use. The data are collected on-line in a single database capable of providing correlation and report generation capability. External, third-party education evaluation experts provide additional guidelines and criteria for the analysis of qualitative and quantitative data facilitating in-depth evaluations of various programs.

SCHEDULE & OUTPUTS

NASA continues to refine a comprehensive system to evaluate its Education Program in order to demonstrate the accomplishment of achievable and measurable goals and objectives. Based on recommendations provided by a study of the NASA Education Program by the National Research Council (NRC), NASA established program goals and defined a comprehensive Education Framework that captures the elements of NASA's Education Program. This framework is detailed in NASA's *Implementation Plan for Education*, and supported by implementation plans developed by the Enterprises and NASA field installations between FY 1995 and the present. NASA utilizes an Internet-based system, for the collection, analysis, evaluation and reporting of standard and program unique data and program outcomes for all NASA education programs.

ACCOMPLISHMENTS AND PROPOSED RESULTS

NASA's Education Data Collection and Evaluation System (EDCATS), continues to add programs incrementally until all NASA education programs are included. As programs compile a firm set of baseline data, selected annual program targets will be established, as needed or required. By FY 2002 the system will be fully operational track data and evaluation metrics for the entire NASA Education Program.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS **MINORITY UNIVERSITY RESEARCH AND EDUCATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousand of Dollars)		
Historically Black Colleges and Universities	36,200	35,871	28,000	SAT 7.2-10
University Research Center Awards				
Institutional Research Awards	300	1,500	1,500	
Principal Investigator Awards	5,500	4,900	3,200	
Math and Science Education Awards	17,900	20,894	16,400	
Partnership Awards	12,500	8,577	6,900	
Enterprise Program Funding *	[17,200]	[17,200]	[20,900]	
Other Minority Universities	30,700	17,900	17,900	SAT 7.2-16
University Research Center Awards				
Institutional Research Awards	400			
Principal Investigator Awards	3,000	3,500	3,000	
Math and Science Education Awards	18,100	11,300	12,300	
Partnership Awards	9,200	3,100	2,600	
Enterprise Program Funding *	[11,600]	[11,600]	[15,300]	
Total Minority University Research Programs	66,900	53,771	45,900	
Total Enterprise Program Funding *	[28,800]	[28,800]	[36,200]	
Total Program Funding to Minority University Research	95,700	82,571	82,100	

* Represents funding included in Enterprise budget request in support of Minority University Programs

ACADEMIC PROGRAMS

MINORITY UNIVERSITY RESEARCH AND EDUCATION PROGRAM

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Distribution of Program Amount by Installation			
Ames Research Center (ARC)	2,526	1,579	1,626
Dryden Flight Research Center (DFRC)	2,119	1,256	1,212
Goddard Space Flight Center (GSFC)	21,633	27,708	20,431
Jet Propulsion Laboratory (JPL)	2,634	1,764	819
Johnson Space Center (JSC)	3,553	1,672	1,921
Kennedy Space Center (KSC)	5,992	3,234	3,138
Langley Research Center (LaRC)	3,260	1,100	1,000
Glenn Research Center (GRC)	13,376	5,239	5,865
Marshall Space Flight Center (MSFC)	7,344	6,300	6,150
Stennis Space Center (SSC)	2,613	1,742	1,480
Headquarters (HQ)	1,850	2,177	2,258
Total	66,900	53,771	45,900

PROGRAM GOALS

The Minority University Research and Education Programs (MUREP) focus primarily on expanding and advancing NASA's scientific and technological base through collaborative efforts with Historically Black Colleges and Universities (HBCU) and Other Minority Universities (OMU), including Hispanic-Serving Institutions (HSI) and Tribal Colleges and Universities (TCU), hereafter referred to as Minority Institutions (MI). NASA's outreach to MI's in FY 2001 will build upon the prior years' investments in MI research and academic infrastructure. Through sufficient infrastructure-building support, exposure to NASA's unique mission and facilities, and involvement in competitive peer review and merit selection processes annually, MI's will be able to contribute significantly to the Agency's strategic goals and objectives. These contributions include the education of a more diverse resource pool of scientific and technical personnel who will be well prepared to confront the technological challenges to benefit NASA and the Nation. In addition

to the Federal mandates for MI's, the strategic goals that guide NASA's MUREP are: (1) To foster research and development activities at MI's which contribute substantially to NASA's mission; (2) To create systemic and sustainable change at MI's through partnerships and programs that enhance research and educational outcomes in NASA-related fields; (3) To prepare faculty and students at MI's to successfully participate in the conventional, competitive research and education process; and (4) To increase the number of students served by MI's to enter college and successfully pursue and complete degrees in NASA-related fields.

STRATEGY FOR ACHIEVING GOALS

NASA employs a comprehensive and complementary array of strategies to achieve these goals for MI's. These strategies include: (1) Working closely with NASA Strategic Enterprises, other government agencies, and interested parties to develop new research and education collaborations and partnerships; (2) Encouraging and providing opportunities for faculty to conduct NASA research early in their careers; (3) Providing incentives for students to enter and remain in mathematics, science and technology disciplines; (4) Establishing measurable program goals and objectives; and (5) Developing and implementing evaluations to assess the effectiveness and outcomes of the programs and financial performance, and thereby improving program delivery and results.

A strategy used to expand MI involvement in competitive peer review processes and to ensure the relevance of research conducted by MI's is to involve NASA Strategic Enterprises early in the development of solicitation notices. Once Headquarters issues the notices, NASA Centers provide advice to prospective grantees, conduct peer reviews of proposals, and provide funding recommendations to the Office of Equal Opportunity Programs (OEOP) and the Strategic Enterprises. After Headquarters makes the selections, the research is returned to the nominating NASA Center(s) or Jet Propulsion Laboratory (JPL) for grant award and/or technical management of the award. OEOP provides policy direction and program oversight. Oversight of the research performed at MI's is conducted by the Strategic Enterprises in collaboration with OEOP. In addition, all MUREP requests for continuation funding are assessed for performance by the NASA Technical Officers and all awards funded for more than 2 years receive on-site reviews.

The successful deployment of these strategies has resulted in the establishment of five different programmatic award categories which apply equally to the HBCU and OMU Programs. These programmatic initiatives are carried out in close collaboration with NASA Strategic Enterprises and Centers/JPL. Strategic Enterprises and Centers/JPL support the MUREP through direct funding, use of their facilities, and commitment of their personnel to serve on Technical Review Committees (TRC) and assist in other facets of program implementation. University Research Centers (URC) and Institutional Research Awards (IRA) receive technical guidance and annual on-site reviews by TRC's. The awards for Principal Investigator (PI), Mathematics, Science, and Engineering (MSE), and Partnerships are managed predominately by personnel at the NASA Centers/JPL. As a result of the involvement of the Strategic Enterprises and NASA Centers/JPL in the MUREP, numerous students and PI's from MI's are knowledgeable about and make significant contributions to the Nation's space program.

In FY 2001, the existing awards in all five programmatic award categories will be maintained. Outreach to MI's will continue to be made in collaboration with the Strategic Enterprises and Centers/JPL to ensure that MI's are knowledgeable of and responsive to the Agency's Strategic Plan. OEOP will continue to set specific program goals that lead to measurable program outcomes that are consistent with the Agency's investment in MI's. These award categories are:

• **University Research Center (URC) Awards** achieve a broad-based, competitive aerospace research capability among the Nation's MI's that will: foster new aerospace science and technology concepts; expand the Nation's base for aerospace research and development; develop mechanisms for increased participation by faculty and students in mainstream research; and increase the productivity of students (who are U.S. citizens and who have historically been underrepresented) with advanced degrees in NASA-related fields. Funding is provided by the Strategic Enterprises. In order to foster closer ties between the URC's and NASA, a Lead NASA Center is designated for each URC and is responsible for directly managing the URC cooperative agreements and for increasing MI involvement in ongoing NASA research and development activities. Collaborations with other NASA Centers, industry, and other universities continue to be strongly encouraged. OEOP continues to maintain responsibility for program policy and oversight. The URC's have formed a National Alliance of NASA University Research Centers (NANURC). This Alliance has established a National Conference of the University Research Centers, created pathways for developing greater collaborations between the URC's, and is exploring avenues for increasing the number of advanced degrees being awarded to disadvantaged students. NASA is strongly supportive of this concept and is actively working with the Alliance to further develop and strengthen their organization.

• **Institutional Research Awards (IRA)** improve academic, scientific and technology infrastructure and broaden the NASA-related science and technology base at MI's. Two awards with different focus areas have been made under this category. The first IRA (Research) award was made in FY 1994 and was limited to only OMU's. These awards provide OMU's with an opportunity to provide a quality learning and research environment in NASA-related areas. The second IRA (Network Resources and Training Sites [NRTS]) was open to all MI's. The IRA (NRTS) award is designed to improve the in-house capability to electronically access science data and computational resources; to develop mechanisms to support, sustain and evolve the network infrastructure of the targeted universities and colleges; and to make MI's more effective in the competitive process for NASA and other science, engineering and technology funding opportunities. IRA awards provide for the acquisition of research equipment and equipment essential to Internet connectivity. The strategies for achieving the IRA (NRTS) goals include: (1) Establishing lead NRTS's; (2) Holding them accountable for providing internet connectivity to other MI's and public schools; and (3) Training students, faculty, and teachers to build computers and effectively utilize the Internet to compliment teaching and research collaborations and delivery. The lead NASA Center, Goddard Space Flight Center (GSFC), manages the IRA (NRTS) under the auspices of GSFC's Minority University - Space Interdisciplinary Network (MU-SPIN) Program. The Office of Equal Opportunity Programs (OEOP), Office of Space Science, and Office of Earth Science collaboratively provide funding and oversight for the GSFC MU-SPIN Program. NASA Strategic Enterprises, NASA Centers, and JPL support IRA programs through direct funding, use of their facilities, and commitment of their personnel to serve on Technical Review Committees (TRC) and assisting in other facets of program implementation. Students and principal investigators involved in IRA (NRTS) spend time on-site at the Centers/JPL throughout the year.

• **Principal Investigators (PI) Awards** provide faculty, who have limited NASA experience, the opportunity to integrate the research and education components of their careers with the unique mission requirements of a specific NASA Center/JPL. Each fiscal year MI's are invited to submit proposals for the Faculty Awards for Research (FAR). The FAR program provides competitive, peer review selection of outstanding and promising engineering, physical and life science-tenured and tenure-track faculty who are capable of contributing to the Agency's research and education objectives. This award provides faculty members with research support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the

transition to achieving competitive awards in the Agency's mainstream research processes. In FY 1996, these awards were expanded to include funding to involve graduate and undergraduate students in research projects.

The primary strategy for implementing the PI Awards for Research is through a competitive peer review and merit selection process in collaboration with the Strategic Enterprises and NASA Centers/JPL. Other strategies include: (1) Have discipline-related personnel at Headquarters and the NASA Centers/JPL who are responsible for serving as points-of-contact for faculty interested in pursuing an award in this category; (2) Give responsibility to the NASA Centers/JPL for conducting the technical evaluations and making selection recommendations to Headquarters for funding consideration; (3) Provide funding to the nominating NASA Center/JPL to make PI Awards for Research; and (4) Hold the NASA Center/JPL responsible for managing the awards and obtaining the research outcomes. By involving MI faculty and students in NASA research, the Agency hopes to increase the interest of traditionally underrepresented communities in the Agency's mission and involve a broader array of America's citizenry in the NASA-sponsored research community.

• **Mathematics and Science Education (MSE) Awards** build upon these institutions' outstanding ability to provide excellence in mathematics, science, engineering and technology (MSET) training while increasing the participation and achievement of socially and economically disadvantaged and/or disabled students in MSET fields at all levels of education. Awards are made in the following three areas: undergraduate and graduate; teacher preparation and enhancement; and precollege activities.

MSE Awards contribute to the national education goals by integrating the contents from the NASA mission into the educational outreach projects at MI's. As a result, NASA contributes to the increase in the number and the strengthening of the skills, knowledge, and interest of students and teachers in mathematics-, science-, engineering-, and technology-based MSET academic programs. MSE awards consist of both unsolicited and solicited awards. The solicited awards are the NASA Precollege Awards for Excellence in Mathematics, Science, Engineering and Technology (PACE/MSET) Program and the Mathematics, Science, and Technology Awards for Teacher and Curriculum Enhancement Program (MASTAP). Both types of MSE awards are reflected in the last two subcategories.

- Undergraduate and Graduate Awards provide scholarships, fellowships, internships, and research opportunities in NASA-related fields, and other services to enhance retention and increase graduation rates. These awards are in response to Congressional direction to increase the number of individuals from underrepresented groups in the pool of graduate researchers. Students must be U.S. citizens and must pursue degrees in NASA-related fields. During the academic year and/or summer, students are required to conduct research relevant to their fields of study at a NASA Center, on a university campus, at a Federal laboratory, or in the aerospace industry. It is expected that these students will form part of the pool from which NASA selects graduate researchers and/or employees.

- Teacher Preparation and Enhancement Awards provide opportunities for MI's to develop diverse and exemplary research-based mathematics, science, technology and geography teacher education curricula that are integrated with content from NASA's mission. It is the Agency's desire that the results will contribute to the participating states' efforts to increase the numbers and percentage of state-certified mathematics, science, technology or geography teachers employed in hard-to-staff elementary, middle and secondary schools not normally served by NASA.

- Precollege Awards offer opportunities for MI's, in collaboration with NASA and local school districts, to provide informal educational opportunities that will enhance the numbers and percentage of students enrolled in mathematics and science college preparatory courses. As a result of participating in these awards, students will gain awareness of career opportunities in MSET fields and exposure to NASA's mission and scientific and technical personnel role models and will enter college pursuing NASA-related career fields.

In FY 1999, additional funding of $10M was included in the FY 1999 Appropriation Bill for VA-HUD-Independent agencies for the Science, Engineering, Mathematics and Aerospace Academy (SEMAA) to replicate the training at ten other sites. These ten sites will be funded through FY 2000. In FY 2001 a competitive solicitation will be offered to merit select new SEMAA sites at minority institutions. The new solicitation will continue the current focus on aero-space, but will be expanded to include curricula related to the other three NASA strategic enterprises of Earth Science, Space Science, and Human Exploration and Development of Space.

• **Partnership Awards** were expanded in FY 1999 and in response to Congressional direction to "expand opportunities and enhance diversity in the NASA sponsored research and education community...achieve a balance between the proportion of NASA funding received by minority institutions of higher education and other institutions of higher education." These awards include (1) Partnership Awards for Innovative and Unique Education and Research (IUER) Projects and (2) Partnership Awards for the Integration of Research into Undergraduate Education (PAIR). The Partnership Awards (IUER) are awarded to MI's in three categories: research, education, or training. These projects strengthen partnerships with NASA Centers and MI's, are innovative and unique, and have potential for long-term support from other sources. The PAIR awards have an inter-disciplinary focus that spans more than one MSET academic program, creating a collaborative effort among different academic departments. To extend the inter-disciplinary focus, the MI's are strongly encouraged to demonstrate in their proposals partnerships with NASA Centers/JPL, with other institutions of higher education, and with the aerospace community. In FY 2000, additional funding of $5.0M was included in the FY 2000 Appropriations Bill for VA-HUD-Independent Agencies for the Partnership Awards Program. The across-the-board, 0.38 percent rescission resulted in this $5.0M being reduced to $4.577M. This funding enabled NASA to continue its efforts to enhance collaboration among MSET academic departments, thereby strengthening the MSET baccalaureate degree-producing capacity of a number of the Nation's HBCU's and OMU's by building upon previous NASA funding. As a result, the outcomes of partnership awards are: (1) innovative interdisciplinary study among MSET academic programs that center on NASA-related course study, research, and technological applications, including collaborative efforts within MSET academic departments; (2) more competitive undergraduate U.S. students, underrepresented in MSET fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter MSET graduate programs or MSET employment; (3) enhanced undergraduate courses and curricula including laboratory-based curricula that foster collaborative educational experiences between faculty members and students leading to institutional faculty development efforts; and (4) model HBCU's and OMU's that integrate NASA-related research into the appropriate areas of the undergraduate curriculum that expose greater numbers of students and faculty to the Agency's cutting-edge technologies. In FY 2001, each NASA Strategic Enterprise will become more involved in Partnership Awards made through Centers.

SCHEDULE & OUTPUTS

MUREP metrics are continually being improved. Performance data measuring participation and program outcomes is obtained through the required submission of annual performance reports and/or on-site or reverse-site reviews of each grant. Each award recipient submits an annual performance report that is reviewed by a NASA Technical Monitor or a Technical Review Committee for qualitative and quantitative progress toward the project's and NASA's program goals and objectives. Continuous assessment of this data has enabled OEOP MUREP to identify performance measures for research and education awards. As part of the grantee's annual reporting requirements, each awardee is now being required to respond to a set of uniform research or education outcomes that enables OEOP to assess progress across all research or education awards. The Uniform Outcomes Report was also designed to avoid duplication of reporting requirements by serving as the grantees' annual performance report. Additionally, as required by Executive Order 12876 for HBCU's, Executive Order 12900 for Educational Excellence for Hispanic Americans (EEHA), and Executive Order13021 for TCU's, at the end of each fiscal year NASA measures its performance against the concluding fiscal year plans that were submitted to the White House Initiative Offices and the Office of Management and Budget. The measures of performance include the number of awards and funding to HBCU's, EEHA's, and TCU's in the following categories: research and development; program evaluation; training; facilities and equipment; fellowships, internships, traineeships, recruitment and IPA's; student tuition assistance, scholarships, and other aid; direct institutional subsidies; third-party awards; private-sector involvement; and administrative infrastructure.

The objectives are to establish uniform outcomes for all NASA MUREP awards and provide compact instruments for uniform collection of data keyed to those outcomes. This process reduces the collection of data to the minimal amounts possible, emphasizes outcomes, and is applicable to any common set of awards. The data collected can be aggregated both horizontally and longitudinally, permits adjustable benchmarking standards to be applied, and is collected electronically over the World Wide Web. A single annual collection of data is used to provide the information necessary for comparative and correlational analysis across research or education projects and information contained in the annual MUREP performance reports, including those required by the White House Initiative Offices on HBCU's, EEHA's, and TCU's. Based on prior years' evaluation results, the following uniform measures of performance have been established for OEOP MUREP research and education awards.

RESEARCH MEASURES OF PERFORMANCE (for URC's, IRA's, PI's, and Partnership (Research) Awards)

- Participants - students, faculty, post-doctoral researchers, research associates supported
- Student Outcomes - degrees awarded, post-graduation plans
- Research Outcomes – referred papers, technical presentations, patents, commercial products, research funds leveraged from other sources

EDUCATION AND TRAINING MEASURES OF PERFORMANCE (for MSE's and Partnership (Education) Awards)

- Participants - students, teachers supported
- High School Student Outcomes - enrollment in Mathematics, Science, Education and Technology (MSET) courses, graduation, enrollment in college, and selection of MSET majors
- Bridge Student Outcomes - completed freshman year in college

- Undergraduate & Graduate Student Outcomes - degrees awarded, post-graduation plans
- Teacher Outcomes - received certificates

IRA (NRTS) Additional metrics are designed to capture the technology and education focus of these awards. Specific metrics will include:

- The number of HBCU's, OMU's, and public schools connected to the Internet
- The number of faculty, teachers, and students trained to utilize the Internet to enhance research and educational outcomes

Continuous assessment of performance through annual evaluations of individual awards and the collection of uniform outcomes across all research and education programs will clearly indicate the impact of NASA MUREP on the scientific and technological base for NASA and the Nation, while minimizing the reporting burden on award recipients.

ACCOMPLISHMENTS AND PROPOSED RESULTS

NASA's MUREP investment in MI's for FY 1999 achieved the following:

1. Funding reached 21 states, the District of Columbia, and Puerto Rico.
2. The number of new competitively peer-reviewed and merit selected MUREP awards totaled 61 in FY 1999.
3. 42 HBCU's were the direct recipients of 209 research and education awards valued at $34.2M.
4. 59 OMU's received 150 awards valued at $19.9M.
   - 34 HSI's received 88 awards valued at $12.5M
   - 7 TCU's received 10 awards valued at $1.1M
   - 20 awards to other institutions of higher learning
   - 13 awards to non-universities such as American Association for the Advancement of Science, National Association for Equal Opportunity in Higher Education, National Action Council for Minorities in Engineering, Hispanic Association of Colleges and Universities
5. Described below are the accomplishments of the Research Measures of Performance and the Education and Training Measures of Performance. The outcomes reported for FY 1999 (reporting period Academic Year 1998-99 and Summer 1999) show great achievements for underrepresented and underserved students, teachers, and faculty.

Research Measures of Performance Accomplishments. The participants included 397 faculty members, 118 research associates, 35 postdoctoral fellows, 804 undergraduates, and 488 graduates. The MI's were able to leverage their NASA MUREP funding of $27 million to an additional $31 million in research support ($8.8 million from other NASA programs and $22 million from other agencies). Technology transfer activities included 53 patents disclosed, applied for, or awarded and 30 commercial products being

developed or marketed. A major goal of MUREP is to increase the number of socially and economically disadvantaged and disabled students receiving advanced degrees and entering into careers in NASA-related fields. Of the 1,292 students involved in these research projects during the reporting period, 804 (62%) participated at the bachelor's degree level, 363 (28%) participated at the master's degree level, and 125 (10%) participated at the doctoral degree level. During the reporting period, 408 students obtained degrees; 275 bachelor's degrees; 110 master's degrees; and 23 doctoral degrees.

Education and Training Measures of Performance Accomplishments. There were 207 MUREP education and training projects conducted at MI's. The programs include precollege and bridge programs, education partnerships with other universities, industry and nonprofit organizations, NRTS, teacher training, and graduate and undergraduate programs. These programs reached a total of 85,529 participants, with the predominant number at the precollege level. The programs achieved major goals of heightening students' interest and awareness of career opportunities in MSET fields and exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research. Formats included Saturday Academies, after school classes, visits to NASA Centers and other scientific and technical industries, museums, hands-on science experiments, and computer training. Grantees reported that 32,087 high school students participated in NASA programs and 7,138 high school students selected college preparatory MSET courses. There were 4,901 high school graduates and 191 bridge students (high school graduates) in NASA programs. Enrolled in college were 945 students, of which 485 selected MSET majors. There were 100 students who successfully completed the freshman year. For the teacher programs, 3,047 teachers participated and 571 teachers received certificates. For undergraduate student programs, 8,242 students participated, 1,326 received degrees, and 197 are employed in a NASA-related field. There were 786 graduate students participating in graduate programs, 180 received degrees, and 49 became employed in a NASA-related field. There were 94 papers published, 65 of which were authored or co-authored by students. There were 59 presentations given at NASA Centers/JPL and 164 presentations at national or international conferences.

• **NASA Strategic Enterprises Involvement with HBCUs and OMUs** continued in FY 1999. The Enterprises invested $28.8M in URC's, IRA's, and other programs and activities at MI's and other educational organizations. The URC awards create a broad-based, competitive aerospace research capability within MI's. This capability fosters new aerospace science and technology concepts; expands the Nation's base for aerospace research and development; and develops mechanisms for increased participation by MI faculty and students into mainstream research. The IRA's and Partnership Awards improve academic, scientific and technology infrastructure. Other initiatives are focused on enhancing diversity and on exposing under-served schools, with significant enrollments of minority students, to Strategic Enterprises' research efforts and educational programs and activities.

• **Summary.** In FY 2000 and FY 2001, NASA MUREP will continue to focus on its goals and strategies to integrate mission-focused research, technology transfer, and education at HBCU's and OMU's. NASA will emphasize partnership awards that leverage NASA's investment by encouraging collaboration among NASA, HBCUs, OMUs and other university researchers and educators, and the aerospace industry. Plans for new awards in FY 2000 include IRA's, PI's, and Math and Science. In FY 2001, new SEMAA sites will be selected through a competitive peer review process. The NASA Strategic Enterprises will become more involved in competitive peer review, merit selection, and oversight of nationally solicited educational and research awards to HBCU's and OMU's managed through NASA Centers and JPL.

BASIS OF FY 2001 FUNDING REQUIREMENT

HISTORICALLY BLACK COLLEGES AND UNIVERSITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Historically Black Colleges and Universities	36,200	35,871	28,000
University Research Center Awards			
Institutional Research Awards	300	1,500	1,500
Principal Investigator Awards	5,500	4,900	3,200
Math and Science Education Awards	17,900	20,894	16,400
Partnership Awards	12,500	8,577	6,900
Enterprise Program Funding *	[17,200]	[17,200]	[20,900]

PROGRAM GOALS

NASA's HBCU program is responsive to Executive Order12876, which requires all Federal agencies to strengthen the capacity of HBCU's to provide quality education and to participate in and benefit from Federal programs. The primary goal of NASA's HBCU program is to enhance institutional infrastructure in NASA-related areas and to provide technical assistance to facilitate planning, development, and the use of new technologies that will ensure the long-term viability and educational outcomes of HBCU's in areas strategic to NASA's mission.

STRATEGY FOR ACHIEVING GOALS

HBCU's were involved in NASA's mission before man set foot on the Moon in 1969. In 1980, President Jimmy Carter signed Executive Order 12232 which established a Federal program "...to strengthen and expand the capacity of HBCU's to provide quality education." Executive Orders issued by Presidents Ronald Reagan and George Bush strengthened this program. NASA's current initiatives for HBCU's are based on two recent Executive Orders. Executive Order12876, signed November 1, 1993, by President William J. Clinton, mandates that agencies "...advance the development of human potential, to strengthen the capacity of HBCU's to participate in and benefit from Federal programs to achieve an increase in the participation by HBCU's in Federal programs." Executive Order12928, signed February 16, 1994, by President Clinton, directs Federal agencies to promote procurement with "...Historically Black Colleges and Minority Institutions." NASA employs a comprehensive strategy to accomplish the HBCU program goals.

ACCOMPLISHMENTS AND PROPOSED RESULTS

As a result of NASA's FY 1999 investment in HBCU's, 42 HBCU's were the recipient of 209 awards which reached more than 36,750 faculty, teachers, and students. The FY 2001 budget estimate includes funding to continue HBCU involvement in all five award categories. Specific accomplishments for each of the categories are as follows:

HBCU FY 1999 Accomplishments	University Research Centers	Principal Investigators	Partnership Awards
Research Population Supported:	517	342	331
Faculty Members	133	55	78
Research Associates	32	25	14
Postdoctoral Fellows	6	3	79
Bachelor's-degree Level Students	198	192	183
Master's-degree Level Students	103	61	35
Doctoral-degree Level Students	45	6	12
Degrees Awarded:	112	86	439
Bachelor's Degrees	62	66	29
Master's Degrees	41	169	10
Doctoral Degrees	9	1	0
% Socially/Economically Disadvantaged or Disabled	96%	84%	88%
Research Accomplishments:			
Refereed Papers or Book Chapters:			
Published	222	48	40
Student (Co) Authors to above	127	23	30
Accepted for Publication	67	20	28
Student (Co) Authors to above	21	12	26
Technical Presentations:			
Total Presentations	333	173	9114
Presentations given by Students	77	61	21
Leverage Achieved (in $M):			
Funding Provided by MUREP	$11.0	$3.0	$3.5
Leverage from Other NASA Programs	$5.3	$1.2	$0.6
Leverage from Other Agencies	$8.9	$2.4	$2.0
Technology Transfer Activities:			
Patents disclosed, applied for, or awarded	5	5	15
Commercial products being developed or marketed	6	58	7
Grant Awards Reporting	11	53	22

HBCU University Research Centers (URC) Awards

Eleven HBCU URC's were established by the Headquarters Office of Space Science (OSS), Office of Aero Space Technology (OAST), Office of Space Flight (OSF), Office of Life & Microgravity Sciences & Applications (OLMSA), Office of Earth Science (OES), and the Office of Equal Opportunity Programs (OEOP). Funding is provided in two stages and the capability of the university determines the amount. In the first stage, more funding is provided to establish a research infrastructure capable of sustaining long-term success in their research and education efforts (up to $2M per university). The funding is reduced in the second stage (not to exceed $1M per university) to recognize and encourage the movement of the URC's towards self-sufficiency through other funding sources. Funding for the following HBCU URC's is provided by the Strategic Enterprises.

University	Research Focus	Enterprises	Lead Center
Clark Atlanta	High Performance Polymers and Composites Research	OAST	GRC
Fisk	Photonic Materials and Devices	OSS	MSFC
Florida A&M	Nonlinear and Nonequilibrium Aeroscience	OAST	LaRC
Hampton	Optical Physics	OSS, OES	LaRC
Howard	Study of Terrestrial and Extraterrestrial Atmospheres	OSS, OES	GSFC
NC A&T State	Aerospace Research	OAST	LaRC
Tuskegee	Food and Environmental Systems for Human Exploration of Space	OAST	JSC
Alabama A&M	Hydrology, Soil Climatology, and Remote Sensing	OES	MSFC
Morehouse School of Medicine	Space Medicine and Life Sciences	OLMSA	JSC
Prairie View A&M	Applied Radiation Research	OSF	JSC
Tennessee State	Automated Space Science	OSS	GSFC

HBCU Institutional Research Awards (IRA)

In FY 1999, 5 HBCU's received renewal awards for IRA (NRTS) from the OES and OSS. These lead NRTS are part of a network that encompasses seven regions that cover the 50 states, Puerto Rico ,and the Virgin Islands. GSFC is the Lead Center for the IRA NRTS Program. The lead NRTS universities are: Prairie View A&M, Elizabeth City State, Morgan State, South Carolina State, and Tennessee State.

In FY 2000, OES and OSS will continue funding for the 5 HBCU IRA (NRTS) to bring advanced computer networking infrastructure and technologies to other institutions of higher education and schools with substantial enrollments of socially and economically disadvantaged and/or disabled students in their regions. These institutions are responsible for information dissemination sites, development of faculty and student network skills, and user working groups. In FY 2000, HBCU's will be invited to participate in the IRA (Research) program for the first time. The IRA (Research) goals include: (1) strengthening and improving core research areas of significance to the NASA mission; (2) increasing the number of students (who are U.S. citizens) conducting space research and

working in NASA-related disciplines; (3) strengthening the research environment of eligible institutions and the capability of individuals by supporting the institutional infrastructure (through the acquisition of research equipment), faculty research, and disadvantaged undergraduate and graduate student researchers; and (4) encouraging technology transfer to the market place and to minority communities. To achieve these objectives, an Agency-wide TRC is assigned to each of the selected IRA (Research) award recipient and is responsible for providing technical guidance. NASA promotes collaboration between its funded IRA institutions, the Centers/JPL, and with entities outside of NASA. Institutions are encouraged to seek funding through NASA's traditional opportunities, as well as other government agencies and private sources to promote future sustainability. IRA awards require substantial undergraduate and graduate student involvement in research projects.

In FY 2000, OAST and OSS will provide funding in the amounts of $500K and $122K respectively for the new IRA (Research) Awards. In FY 2001, OES and OSS will continue funding the 5 HBCU IRA (NRTS), and in FY 2001 OAST and OSS will provide funding similar to that of FY 2000 for the new IRA (Research) Awards.

HBCU Principal Investigator (PI) Awards

The PI Awards for Research are composed of MUREP solicited (also known as Faculty Awards for Research or FAR) and unsolicited (or Other Research and Technology) awards. FAR grants provide for research and student support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the transition to achieving competitive awards in the Agency's mainstream research activities. The number of unsolicited awards depends on funding provided to MUREP, with the priority being on FAR awards. The majority of HBCU research is funded through competitive peer review and merit selection processes to enhance opportunities for participation in the Agency's mainstream research capabilities. Additionally, the pool of socially and economically disadvantaged students with research experience and interest in pursuing advanced MSET degrees in the fields of science, engineering, and mathematics will increase through faculty support.

In FY 1999, funding was provided for 14 third-year awards, 22 second-year awards, and 11 first-year awards. In FY 2000, funding is available for 22 third-year awards, 11 second-year awards, and 10 new FAR awards. In FY 2001 funding will be provided for 11 third-year awards and 10 second-year awards.

HBCU Math and Science Education Awards

The Math and Science Education Awards are composed of unsolicited awards and awards made based on solicitations. Primary funding supports the following four focus areas: undergraduate awards; graduate awards; precollege awards; and teacher enhancement and preparation awards.

During the FY 1999 reporting period (Academic Year 1998–99 and Summer 1999), 98 MUREP education and training projects were conducted at HBCU institutions. The programs included precollege and bridge programs, education partnerships with other universities, industry and nonprofit organizations, NRTS, teacher training, and graduate fellows and/or undergraduate programs. These programs reached a total of 35,651 participants, with the predominant number at the precollege level. The programs achieved major goals of (1) heightening students' interest and awareness of career opportunities in MSET fields, and (2) exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and

other educational activities. Grantees reported 11,740 high school students in NASA programs and 1,144 high school students selected college preparatory MSET courses. There were 416 high school graduates, 337 enrolled in college, and 61 selected MSET majors. There were 111 high school graduates (bridge students) in NASA programs and 54 students who successfully completed their freshman year. There were 1,736 teachers in teacher programs and 320 teachers received certificates. For undergraduate student programs, 711 students participated, 193 received degrees, 22 are employed in a NASA-related field. There were 98 graduate students reported in the survey, 12 received degrees, and 5 are employed in a NASA-related field. There were 34 papers published, 5 of which were authored or co-authored by students. There were 22 presentations given at NASA Centers and 77 presentations at national and international conferences.

The FY 2000 Appropriations Bill for VA-HUD-Independent Agencies provided additional funding for NASA to make awards to Morgan State University ($1.6M), Texas College ($1.0M), and Spelman College ($1.0M). The across-the-board, .038 percent rescission resulted in these additional amounts being decreased as follows: $1.464M to Morgan State University, $0.915M to Texas College, and $0.915M to Spelman College. In FY 2000, funding was provided for 3 third-year and 5 second-year MASTAP awards and 11 third-year and 11 second-year PACE awards. New HBCU MASTAP and new PACE awards will be selected to replace expiring awards. In FY 2001, funding will be available for the second-year MASTAP and PACE awards selected in FY 2000, for 5 third-year MASTAP awards, and for 11 third-year PACE awards.

Additionally, in an effort to be responsive to Congressional direction to "strengthen graduate science, mathematics, engineering, and technology education at HBCU's" and to address the severe under representation of African-Americans at the doctoral level, NASA will begin a 5-year pilot graduate fellowship program at HBCU's in FY 2000. The program will be continued in FY 2001.

HBCU Partnership Awards

In FY 1999, 42 Partnership Awards for Innovative and Unique Education and Research (IUER) Projects were competitively awarded to HBCU's in 11 states and the District of Columbia. Four Partnership Awards for the Integration of Research into Undergraduate Education (PAIR) were continued for the second year of the five-year awards.

The FY 2000 Appropriation Bill for VA-HUD-Independent Agencies provided additional funding of $5.0M for Partnership Awards. The across-the-board, 0.38 percent rescission resulted in this amount being decreased to $4.577M. In FY 2000, the 42 Partnership (IUER) Awards will receive second-year funding, the 4 PAIR Awards will receive third-year funding, and new PAIR Awards will be made. In FY 2001 the 4 PAIR Awards (selected in FY 1999) will receive the fourth year of funding and the new PAIR Awards (selected in FY 2000) will receive second-year funding. In FY 2001, each NASA Strategic Enterprise will become more involved in Partnership Awards made through Centers.

NASA Strategic Enterprises Involvement with HBCUs

For the first time, in FY 1999, the Strategic Enterprises' funds were applied to education awards as well as research awards. In collaboration with OEOP, the Office of Earth Science (OES) solicited proposals from a broad range of education and research professionals to develop and implement Earth System Science (air, land, water, and life interactions) Education Programs targeted for kindergarten through postdoctoral levels. As a result, in FY 1999, OES made an initial investment of $292K in two HBCU's for 3 three-year awards. In FY 2000 and FY 2001, OES's investment will be $275K and $279K, respectively. OES will also contribute $122K to new Partnership Awards (PAIR) to be selected in FY 2000 and will provide similar support in FY 2001. In FY 2000, the Office of Space Science (OSS) and OEOP will jointly sponsor a new initiative in space science to competitively award, for up to three years, grants for education and research proposals to MI's. The goals of the education and research program are: (1) the development of space science-related academic capabilities and programs at MI's; and (2) the enhancement/development of faculty and students in space science-related fields at MI's through the establishment of partnerships and exchange programs in research and education with NASA-supported space science research groups. The amount of each award will be between $50K and $250K. The HBCU funding for FY 2000 is $1.5M. In FY 2001, similar funding will be provided for the second year of the three-year grants.

In FY 2001, OEOP will provide $250K to support HBCU's participation in the OES University Earth System Science (UNESS) Project. These funds are to be used to facilitate the significant and meaningful participation of HBCU's and OMU's in the UNESS Project. After selections for the UNESS Project are made, OEOP will evaluate the selected proposals to determine the degree to which the proposal meets the requirements of increasing the capabilities of HBCU's and OMU's to participate in earth science/applications mission. After a determination is made, funding will be made available for HBCU's participation in the concept study phase.

BASIS OF FY 2001 FUNDING REQUIREMENT

OTHER MINORITY UNIVERSITIES

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Other Minority Universities	30,700	17,900	17,900
University Research Center Awards			
Institutional Research Awards	400		
Principal Investigator Awards	3,000	3,500	3,000
Math and Science Education Awards	18,100	11,300	12,300
Partnership Awards	9,200	3,100	2.600
Enterprise Program Funding *	[11,600]	[11,600]	[15,300]

PROGRAM GOALS

The primary goal of NASA's OMU program is to increase the opportunities for HSI's, TCU's, and educational organizations serving substantial numbers of people with disabilities to participate in and benefit from NASA's research and education programs.

STRATEGY FOR ACHIEVING GOALS

NASA established the OMU program per P. L. 98-371, House Report 98-803, and Senate Report 98-506 to "...review institutions of higher learning having significant minority enrollments to find ways to build closer relations with such schools, meet NASA's research objectives and increase the number of individuals from underrepresented groups in the pool of graduate researchers ...build a closer relationship with institutions serving significant numbers of minorities. In addition, Executive Order12900 (February 22, 1994) mandated that agencies increase Hispanic American participation in Federal education programs where Hispanic Americans currently are under served; Executive Order12928 (September 16, 1994) directed Federal agencies to promote procurement with "...Historically Black Colleges and Minority Institutions;" and P.L. 103-327 directed the establishment of URC's at the HSI's. Executive Order 13021(October 19, 1996) directed Federal agencies and departments to strengthen their relationships with Tribal Colleges and Universities. In response, NASA is developing a 5-year plan of action and submitted it first annual accomplishment reports to the White House Initiative Office for Tribal Colleges. Present awards to TCU's are encouraged within the five programmatic awards.

Although similar to the HBCU Program strategies and because of the differences in the evolution of MI's and the particularities of Federal mandates for HBCU's and Hispanic Americans, NASA's approach and implementation plan have been adjusted to incorporate these factors. For example, the Federal mandate for Hispanic Americans directs Federal agencies to "....improve educational outcomes for Hispanic Americans participating in Federal education programs...". As a result, the Agency has placed greater emphasis on mathematics and science awards than on institutional research awards.

ACCOMPLISHMENTS AND PROPOSED RESULTS

As a result of NASA's FY 1999 investment in OMU's, 54 OMU's were the recipient of 109 awards which reached more than 50,560 faculty, teachers, and students. Specific accomplishments for each of the categories are as follows:

OMU FY 1999 Accomplishments	University Research Centers	Institutional Research Awards	Principal Investigators	Partnership Awards
Research Population Supported:	233	219	174	26
Faculty Members	44	48	33	6
Research Associates	9	27	8	3
Postdoctoral Fellows	4	6	6	1
Bachelor's-degree Level Students	65	78	81	7
Master's-degree Level Students	95	31	33	5
Doctoral-degree Level Students	16	29	13	4
Degrees Awarded:	72	38	49	12
Bachelor's Degrees	47	28	35	8
Master's Degrees	20	6	11	3
Doctoral Degrees	5	4	3	1
% Socially/Economically Disadvantaged or Disabled	94%	89%	71%	75%
Research Accomplishments:				
Refereed Papers or Book Chapters:				
Published	153	68	22	8
Student (Co) Authors to above	68	34	17	0
Accepted for Publication	78	44	8	3
Student (Co) Authors to above	10	33	6	12
Technical Presentations:				
Total Presentations	186	124	64	19
Presentations given by Students	86	37	27	5
Leverage Achieved (in $M):				
Funding Provided by MUREP	$3.2	$3.9	$1.7	$0.4
Leverage from Other NASA Programs	$0.1	$1.2	$0.5	

Leverage from Other Agencies	$4.1	$3.1	$1.2	$0.4
Technology Transfer Activities:				
Patents disclosed, applied for, or awarded	13	12	2	1
Commercial products being developed or marketed	4	3	2	
Grant Awards Reporting	3	5	24	3

OMU University Research Centers (URC)

Three OMU URC Awards were established by the Headquarters Office of Space Science (OSS), Office of Aero Space Technology (OAST), Office of Space Flight (OSF), Office of Earth Science (OES), and Office of Equal Opportunity Programs (OEOP). Funding for the following OMU URC's is provided by the Strategic Enterprises.

University	Research Focus	Enterprises	Lead Center
New Mexico	Autonomous Control Engineering	OAST	ARC
Texas at El Paso	Pan American Center for Earth and Environmental Studies	OES	GSFC
Puerto Rico at Mayaguez	Tropical Center for Earth and Space Sciences	OSS, OES	GSFC

OMU Institutional Research Awards (IRA)

The IRA (Research) goals include: (1) strengthening and improving core research areas of significance to the NASA mission; (2) increasing the number of students who are U.S. citizens conducting space research and working in NASA-related disciplines; (3) strengthening the research environment of eligible institutions and the capability of individuals by supporting the institutional infrastructure (through the acquisition of research equipment), faculty research, and disadvantaged undergraduate and graduate student researchers; and (4) encouraging technology transfer to the market place and to minority communities. To achieve these objectives, an Agency-wide TRC is assigned to each of the selected IRA (Research) award recipients and is responsible for providing technical guidance. The IRA (NRTS) grants offer advanced computer networking infrastructure and technologies to other institutions of higher education and schools with substantial enrollments of socially and economically disadvantaged and/or disabled students in their regions. These institutions are responsible for information dissemination sites, development of faculty and student network skills, and user working groups. NASA promotes collaboration between its funded IRA institutions, the Centers/JPL, and with entities outside of NASA. Institutions are encouraged to seek funding through NASA's traditional opportunities, as well as other government agencies and private sources to promote future sustainability. IRA awards require substantial undergraduate and graduate student involvement in research projects.

In FY 1999, renewal awards were granted to 5 OMU IRA (Research) and 2 OMU IRA (NRTS). In FY 2000 and FY 2001, OSS, OES, and OAST will continue funding for the 5 IRA (Research) and the 2 IRA (NRTS), as follows:

University	Research Focus	Enterprises	Lead Center
IRA (Research):			
California State-Los Angeles	Use of Decentralized Control in Design of a Large Segmented Space Reflector	OSS	JPL
Florida International	High Performance Database Management with Application to Earth Sciences	OES	GSFC
Puerto Rica at Rio Piedras	Land Management in the Tropics and its Effects on the Global Environment	OES	MSFC
City College of New York	Tunable Solid State Laser and Optical Imaging	OAST	LaRC
New Mexico Highlands	Alliance for Nonlinear Optics	OAST	MSFC
IRA (NRTS):			
City College of New York	Urban Collaboration for Network Connectivity and Internet Access	OSS, OES	GSFC
Texas at El Paso	Network Resources Training Sites	OSS	GSFC

In FY 2000, OAST and OSS will participate in the selection of new IRA (Research) Awards and will provide OMU funding of $400k and $657K, respectively. FY 2001, OAST and OSS will provide similar funding for the new IRA (Research) Awards.

OMU Principal Investigator (PI) Awards

The PI Awards for Research are composed of MUREP solicited (also known as Faculty Awards for Research or FAR) and unsolicited (or Other Research and Technology) awards. FAR grants provide for research and student support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the transition to achieving competitive awards in the Agency's mainstream research activities. The number of unsolicited awards depends on funding provided to MUREP, with the priority being on FAR awards. Through the competitive process for awards, opportunities for participation in the Agency's mainstream research will expand as recipients' research capabilities are enhanced through interaction with NASA researchers and faculty. Additionally, the pool of disadvantaged students with research experience and interest in pursuing advanced degrees in the fields of science, engineering, and mathematics will increase through faculty support.

In FY 1999, funding for 4 third-year, 16 second-year and 7 new FAR awards was provided. In FY 2000, funding will be provided for 16 third-year, 7 second-year, and 10 new FAR awards. In FY 2001, funding will be provided for10 second-year awards and 7 third-year awards.

OMU Math and Science Education Awards

The Math and Science Education Awards are composed of unsolicited awards and awards made based on solicitations. Primary funding supports the following four focus areas: undergraduate awards; graduate awards; precollege awards; and teacher enhancement and preparation awards.

During the FY 1999 reporting period (Academic Year 1998–99 and Summer 1999), 109 MUREP education and training projects were conducted at OMU institutions. The institutions conducted precollege and bridge programs, education partnerships with other universities and industry, NRTS, teacher training, and graduate and undergraduate programs. These programs reached a total of 49,914 participants, predominantly at the precollege level and achieved major goals of heightening students' interest and awareness of career opportunities in MSET fields, and exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and other educational activities. In FY 1999, NASA continued a very meaningful relationship with the Hispanic Association of Colleges and Universities (HACU) through Proyecto Access, a consortium through which HACU linked eight HSI's together to conduct 8-week MSET summer programs. Grantees reported 20,347 high school students in NASA programs and 5,994 high school students selected college preparatory MSET courses. There were 4,485 high school graduates, 608 enrolled in college, and 424 who selected MSET majors. There were 90 high school graduates (bridge students) in NASA programs and 46 students successfully completed the freshman year. There were 1,311 teachers in teacher programs and 251 teachers received certificates. There were 7,531 undergraduate students; 1,133 received undergraduate degrees; and 175 are employed in a NASA-related field. There were 688 graduate participants; 168 received graduate degrees; and 44 are employed in a NASA-related field. There were 60 papers published, all of which were authored or co-authored by students. There were 37 presentations given at NASA Installations and 87 presentations given at national and international conferences. In FY 1999, the OMU MASTAP's continued to contribute to the National Education Goals by enhancing the ability of pre-service and in-service teachers to teach mathematics and science in schools under served by NASA. This was achieved through the development of special courses, curricula, instructional models, publications, presentation of academic papers, and teacher certifications. Pre-service teachers gained valuable classroom experience while at the same time providing extra attention to students in schools with large numbers of disadvantaged students. In the process, several teachers completed master's degrees. These programs have had a positive impact on both the universities that implement them and on the school districts with which they have partnered. Effective and innovative instructional materials, curricula, and models developed by MASTAP programs are distributed to a broad audience. In FY 1999, additional funding of $10M was included in the FY 1999 Appropriation Bill for VA-HUD-Independent agencies for the Science, Engineering, Mathematics and Aerospace Academy (SEMAA) to replicate the training provided to other sites. The three components are as follows: (1) Living In Space for the K - 4th graders has classes for both students and parents to institutionalize math and science in the home; (2) Exploring the Solar System for 5th- 8th graders increases their awareness of MSET skills and the use of laboratory equipment; (3) Discovering Aeronautics for 9th-12th graders was developed to be used with Glenn Research Center or the Mobile Aeronautics Education Lab when available. FY 1999 funds will continue the program through FY 2000.

In FY 2000, funding will be available for one third-year and 4 second-year MASTAP awards and 5 third-year and 5 second-year PACE awards. In FY 2000, new MASTAP and new PACE awards will be selected. In FY 2001, funding will be provided for 4 third-year MASTAP Awards, second-year MASTAP awards (selected in FY 2000), 5 third-year PACE Awards, and second-year PACE awards (selected in FY 2000).

OMU Partnership Awards

In FY 1999, 30 new Partnership Awards for Innovative and Unique Education and Research (IUER) Projects were competitively awarded to OMU's in 8 states. Three new Partnership Awards for the Integration of Research into Undergraduate Education (PAIR) were continued for the second year of the five-year awards. In FY 2000, the 30 Partnership Awards will receive second-year

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 2001 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

This appropriation provides funding for mission support and includes: safety, mission assurance, engineering and advanced concepts activities supporting agency programs; salaries and related expenses in support of research in NASA field installations; design, repair, rehabilitation and modification of institutional facilities and construction of new institutional facilities; and other operations activities supporting conduct of agency programs.

STRATEGY FOR ACHIEVING GOALS

Funding included in the Mission Support appropriation supports agency-wide activities which touch all of NASA's programs:

Safety, Mission Assurance, Engineering, and Advanced Concepts: This includes funding for programs to assure the safety and quality of NASA missions, through the development, implementation and oversight of agencywide safety, reliability, maintainability and quality assurance policies and procedures. It also includes funding for engineering policies, standards, and guidelines to improve analysis tools and test methods for design and verification of spaceflight systems, and study of advanced concepts for possible future technology development and mission use.

Mission Communication Services: This includes funding for the operation of the tracking, telemetry, command, data acquisition, and communications and data processing activities that are required by all NASA projects. In the FY 2001 budget, Space Communications Services is moved from Mission Support into a consolidated Space Operations budget in the SAT account.

Research and Program Management: This includes funding for the salaries, benefits, travel requirements and other support of the civil service workforce, and the necessary funding for all of NASA's administrative functions in support of research in NASA's field centers.

Construction of Facilities: This activity provides for facility construction activities to preserve NASA's infrastructure and enable NASA's missions; environmental compliance and restoration activities, design of facilities projects, and advanced planning and critical functional leadership activities related to future facilities needs. Activities supported include construction projects to repair and modernize the basic infrastructure and institutional facilities at NASA centers, as well as activities in support of environmental compliance and restoration requirements.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 2001 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1999	FY 2000	FY 2001
MISSION SUPPORT	**2,499.5**	**2,532.2**	**2,584.0**
SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS	35.6	43.0	47.5
MISSION COMMUNICATIONS SERVICES	185.8	89.7	--
RESEARCH AND PROGRAM MANAGEMENT	2109.6	2217.6	2290.6
CONSTRUCTION OF FACILITIES	168.5	181.9	245.9

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

MISSION SUPPORT

For necessary expenses, not otherwise provided for, in carrying out mission support for human space flight programs and science, aeronautical, and technology programs, including research operations and support; maintenance; construction of facilities including [repair, rehabilitation,] revitalization and modification of facilities, [minor construction of new facilities and additions to existing facilities, facility planning and design, environmental compliance and restoration, and acquisition or condemnation of real property, as authorized by law; program management, personnel and related costs, including uniforms or allowances therefore, as authorized by 5 U.S.C. 5901-5902; travel expenses; purchase, lease, charter, maintenance, and operation of mission and administrative aircraft; not to exceed [$35,000] $40,000 for official reception and representation expenses; and purchase (not to exceed 33 for replacement only) and hire of passenger motor vehicles, [$2,515,100,000] $2,584,000,000 to remain available until September 30, [2001] 2002. *(Departments of* Veterans *Affairs* and Housing and *Urban Development, and Independent Agencies* Appropriations *Act, 2000.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

		BUDGET PLAN	
	FY 1999	FY 2000	FY 2001
MISSION SUPPORT	**96.5**	**127.3**	**65.8**
SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS	0.2	0.3	0.3
MISSION COMMUNICATIONS SERVICES	43.3	62.1	--
RESEARCH AND PROGRAM MANAGEMENT	48.9	61.4	63.6
CONSTRUCTION OF FACILITIES	4.1	3.5	1.9

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 ESTIMATES

DISTRIBUTION OF MISSION SUPPORT BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Safety, Mission Assurance,	1999	35,600	6,982	1,244	2,204	119	6,399	255	3,665	1,528	6,149	3,589	3,466
Engineering, and	2000	43,000	6,934	880	2,255	170	5,950	350	5,148	2,183	7,903	6,947	4,280
Advanced Concepts	2001	47,500	6,860	965	2,555	125	5,725	425	7,180	2,160	8,900	7,755	4,850
Space Communications	1999	185,800	34,400	30,200	46,900	0	0	0	0	0	67,500	3,800	3,000
	2000	89,700	47,000	14,000	7,700	0	0	0	0	0	17,500	2,800	700
	2001	0	0	0	0	0	0	0	0	0	0	0	0
Research and Program	1999	2,109,600	334,600	246,300	287,800	41,300	170,900	56,700	214,400	194,000	334,000	0	229,600
Management	2000	2,217,624	340,100	255,300	294,954	45,400	174,029	58,923	222,894	198,600	349,200	0	278,224
	2001	2,290,600	361,900	248,100	310,500	43,300	186,800	61,700	240,400	205,600	367,700	0	264,600
Total Construction of	1999	168,500	21,819	20,875	30,136	12,600	14,875	4,357	9,307	17,319	18,513	15,810	2,889
Facilities	2000	181,900	14,050	31,500	25,365	10,925	12,655	6,582	20,270	19,303	21,320	17,138	2,792
	2001	245,900	31,820	49,260	33,010	16,760	21,605	5,910	17,900	25,030	22,360	19,120	3,125
TOTAL MISSION SUPPORT	1999	2,499,500	397,801	298,619	367,040	54,019	192,174	61,312	227,372	212,847	426,162	23,199	238,955
	2000	2,532,224	408,084	301,680	330,274	56,495	192,634	65,855	248,312	220,086	395,923	26,885	285,996
	2001	2,584,000	400,580	298,325	346,065	60,185	214,130	68,035	265,480	232,790	398,960	26,875	272,575

SAFETY, MISSION ASSURANCE, ENGINEERING AND ADVANCED CONCEPTS

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SAFETY & MISSION ASSURANCE
OFFICE OF THE CHIEF ENGINEER
OFFICE OF THE CHIEF TECHNOLOGIST

SAFETY, MISSION ASSURANCE, ENGINEERING & ADVANCED CONCEPTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
	(Thousands of Dollars)		
Safety and Mission Assurance	25,900	25,200	25,200
Engineering	5,300	13,100	17,500
Advanced Concepts	4,400	4,700	4,800
Total	35,600	43,000	47,500
Distribution of Program Amount by Installation			
Johnson Space Center	6,982	6,934	6,860
Kennedy Space Center	1,244	880	965
Marshall Space Flight Center	2,204	2,255	2,555
Stennis Space Center	119	170	125
Ames Flight Research Center	6,399	5,950	5,725
Dryden Research Center	255	350	425
Langley Research Center	3,665	5,148	7,180
Glenn Research Center	1,528	2,183	2,160
Goddard Space Flight Center	6,149	7,903	8,900
Jet Propulsion Laboratory	3,589	6,947	7,755
Headquarters	3,466	4,280	4,850
Total	35,600	43,000	47,500

GENERAL

The Safety, Mission Assurance, Engineering, and Advanced Concepts (SMAEAC) budget supports the activities of the Office of Safety and Mission Assurance (OSMA), the Office of the Chief Engineer (OCE), and the Office of the Chief Technologist (OCT). These three Offices advise the Administrator, oversee NASA programs, develop Agency-wide policies and standards, and support the technology requirements of NASA flight programs.

PROGRAM GOALS

SMAEAC's goal is to enable safe and successful NASA programs. SMAEAC funding is an investment that generates policies, guidance, tools, independent reviews, and other outputs to provide conditions in which programs can be safe and successful.

STRATEGY FOR ACHIEVING GOALS

The Safety and Mission Assurance (SMA) area assures that sound and robust SMA processes and tools are in place to enable safe and successful missions. This area establishes SMA strategies, policies, and standards, and ensures that SMA disciplines are appropriately applied throughout the program life cycle. SMA also provides analysis, oversight, and independent assessment (IA) of programs, and flight & ground operations to ensure that suitable attention is placed on risk, missions are conducted safely, and there is a high probability of meeting Agency objectives. SMA funds research, development, pilot project application, and evaluation of tools, techniques, and practices that advance NASA's SMA capabilities in areas such as facility and operational safety, risk management, human reliability, software assurance, and probabilistic risk analysis. Funding is also provided to develop SMA training courses.

The Office of the Chief Engineer (OCE), funded under the 'Engineering' line, oversees NASA's strategic crosscutting processes to "Provide Aerospace Products and Capabilities" and independently evaluates ongoing programs, proposed concepts, and options for new programs. The OCE establishes policies, standards, and technical capabilities to improve NASA engineering practices. The NASA Electronics Program supports evaluation and introduction of advanced electronic parts and packaging technology into NASA programs.

The Office of the Chief Technologist (OCT), funded under the 'Advanced Concepts' line, is NASA's overall advocate for advanced technology. As such, the OCT advises the Administrator on technology matters and develops a NASA-wide investment strategy for innovative and advanced technology. The office leads the development of NASA-wide technology goals and objectives and oversees NASA technology policies, programs, processes, and capabilities. OCT also sponsors the NASA Institute for Advanced Concepts (NIAC), which helps advance potentially revolutionary technologies that may enable NASA strategic objectives requiring technology readiness ten to twenty years into the future.

ACCOMPLISHMENTS AND PLANS

In FY 1999, NASA achieved a lost time injury rate of 0.19 incidents per 200,000 workhours against a goal of 0.32. (Note: while the FY 1999 injury rate was unusually low, the goal does reflect progress on the historical trend.) FY 1999 saw research, development,

pilot application, and evaluation of SMA tools, techniques and practices in disciplines such as operational and facility safety, risk management, quantitative risk analysis, software assurance, failure detection and prevention, and human reliability with the goal of enabling NASA safety and mission success. Revisions to SMA policies and guidance (NASA Occupational Safety and Health Programs; NASA Safety Manual; Emergency Preparedness Program Plan, Process and Guidelines; Planning, Developing and Managing an Effective Reliability and Maintainability Program) were completed. OSMA provided support to and independent review of the International Space Station (ISS), Space Shuttle (4 missions), and science programs (including 9 expendable launch vehicle (ELV) payload launches). More than 3,000 students received SMA training. All NASA installations were third-party certified to ISO 9001, and all Centers completed the first round of SMA Process Verifications to review SMA process effectiveness and efficiency. An Agency Safety Initiative was developed and deployed. NASA assurance processes for expendable launch vehicles (ELVs) were evaluated and a Radiological Emergency Response Plan for Cassini's Earth gravity assist was developed. Within the Office of the Chief Engineer (OCE), five Independent Assessments of planned programs (including X38-CRV), and 25 Independent Annual Reviews (IARs) of ongoing programs were conducted in FY 1999. To implement OMB Circular A-119 and PL 104-113, 700 private Voluntary Consensus Standards (VCS) were processed for NASA adoption. 11 NASA Technical Standards were added to the NASA Preferred Technical Standards System and several NASA-led international standards for space systems were published by ISO. Management of the NASA Electronics Program (NEP) transferred from the Office of Space Science to OCE in FY 1999. This ongoing effort performs radiation testing and application readiness assessments of advanced electronics technologies. A simplified dynamic test method to reduce project testing cost and schedule was verified by conducting a flight experiment on STS 96. Within the Office of the Chief Technologist (OCT), the NIAC awarded FY 1999 Phase II studies. An inventory of NASA's technology investments along with long-term technology planning efforts were also supported.

The FY 2000 safety goal is 0.30 lost time incidents per 200,000 workhours. ISS independent review continues. Support and review will be provided to 7 Shuttle and 13 ELV and payload missions. OSMA will continue to identify, develop, update, and evaluate SMA tools, techniques and practices (including risk management, operational safety, quantitative risk analysis, software assurance, failure detection and prevention, and human reliability) to enable safety and mission success. Activities to maintain ISO 9001 certification, subsequent rounds of Process Verifications, and SMA training will continue. Policy and process evaluations will be conducted as needed in FY 2000, and any missions carrying nuclear materials will be reviewed for safety. In OCE, ten programmatic Independent Assessments, including Deep Space-3 and Next Generation Space Telescope are anticipated in FY 2000. Integration of VCS into the NASA system completes in FY 2000. Development of NASA and international standards continues. NEP funding is transferred to OCE in FY 2000 to align program management with funding, and integration of various databases on electronics will be initiated. The National Research Council assessment of Advanced Engineering Environments will complete in FY 2000. Cost estimating and analysis efforts will be improved and focused to support various program reviews and the Independent Assessment function. In OCT, NIAC will award new rounds of Phase I studies in FY 2000. Technology inventory and planning efforts continue.

FY 2001's lost time injury rate goal is 0.28 incidents per 200,000 workhours. Independent review of the ISS continues beyond FY 2001, and 8 Shuttle and 11 ELV and payload missions will be supported. OSMA will continue to identify, develop, update, and evaluate SMA tools, techniques and practices (including risk management, operational safety, quantitative risk analysis, software assurance, failure detection and prevention, and human reliability) to enable safety and mission success. Activities to maintain ISO 9001 certification, subsequent rounds of Process Verifications, and SMA training will continue. Policy and process evaluations will be conducted as needed through FY 2001, and any missions carrying nuclear materials will be reviewed for safety. In OCE, IARs

continue, and about 10 programmatic Independent Assessments are anticipated. The NASA Preferred Standards system, with on-line access to adopted standards, will be fully operational in FY 2001, and development of NASA Technical Standards and international standards will continue. NEP will develop new methods for technology qualification and reliability assessment based on modeling and physics of failure in FY 2001, and electronics database integration completes. The cost estimating and analysis function will be fully operational. Systems engineering efforts will be realigned to support the Systems Management function and complement the ISE in FY 2001. In OCT, NIAC will award another round of Phase I studies as well as Phase II follow-ons to the FY 2000 Phase I studies in FY 2001. Technology inventory and planning support will continue.

MISSION SUPPORT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **SPACE COMMUNICATIONS SERVICES**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Space Network	110,300	36,100	--	MS 2-4
NASA Integrated Services Network	75,500	53,600	--	MS 2-9
[Reimbursements [non-add]]	[45,900]	[43,000]	--	
Total	185,800	89,700	--	
Distribution of Program Amount by Installation				
Johnson Space Center	34,400	47,000	--	
Kennedy Space Center	30,200	14,000	--	
Marshall Space Flight Center	46,900	7,700	--	
Goddard Space Flight Center	67,500	17,500	--	
Jet Propulsion Laboratory	3,800	2,800	--	
Headquarters	3,000	700	--	
Total	185,800	89,700	--	

Note -- Beginning in FY 2001, funding for all these activities is requested under the Science, Aeronautics and Technology appropriation under the Space Operations program.

PROGRAM GOALS

The Space Communications goal is to provide high quality, reliable and cost-effective space operations services, which enable Enterprise, mission execution. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center in Houston, manages the telecommunications, data processing, mission operation, and mission planning services needed to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. In line with the National Space Policy, the SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participate with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for operational communications and associated information handling services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests.

The Space Communication Services segment of NASA's Space Communications program is composed of two major elements. The Space Network element provides communications support to human space flight missions and low-Earth orbital spacecraft compatible with the Tracking and Data Relay Satellite (TDRS) system and to expendable launch vehicles and research aircraft. The NASA Integrated Services Network (NISN) program element provides telecommunications interconnectivity among NASA flight support networks, project and mission control centers, data processing centers and facilities, contractor facilities, and investigator science facilities located throughout the nation and the world.

STRATEGY FOR ACHIEVING PROGRAM GOALS

The Space Operations program provides command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university research and laboratory facilities, and the investigating scientists. The program provides scheduling, network management and engineering, pre-flight test and verification, flight system maneuver planning and analysis. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises.

The Space Operations program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the evaluation and coordination of data standards and communication frequencies to be used in the future.

Many science and exploration goals are achieved through inter-agency or international cooperation. Services from NASA's Space Operations assets are provided through collaborative agreements with other U.S. Government agencies, commercial space enterprises, academia, and international cooperative programs. Consistent with the National Space Policy, NASA procures commercially available goods and services to the fullest extent feasible, NASA develops selected technologies which leverage commercial investments and enable the use of existing and emerging commercial telecommunications services to meet NASA's Space Operations needs. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems and services.

The Consolidated Space Operations Contract (CSOC) was successfully implemented on 1 January 1999 under the direction of the Space Operations Management Office and Lockheed Martin Space Operations Company as the Prime Contractor. CSOC provides end-to-end space operations mission and data services to both NASA and non-NASA customers. CSOC is a $3.44B contract with a Basic Period of Performance from January 1999 through December 2003 and an option period though December 2008. The contract is a Performance Based Cost Plus Award Fee (CPAF) with possible conversion to Fixed Price Incentive Fee (FPIF) within 2 years. A total of nine contracts were consolidated at the inception of CSOC, a further four contracts have been consolidated in FY 2000 to date and two further contracts are to be consolidated in FY 2001. CSOC reflects a significant change in NASA philosophy as accountability and day to day direction for providing space operations services shifts from NASA to the CSOC contractor.

Beginning in FY 2001, funding for these activities is requested under the Science, Aeronautics and Technology appropriation under the Space Operations program, so as to link these activities more directly with the agency programs which constitute the principal users of these facilities and services. The consolidation of Space Communication Services, along with that part of the Space Operations program already included in the SAT appropriation (Mission Communication Services), will enable the Space Operations Management Office (SOMO) at Johnson Space Center to more effectively manage the Space Operations program. This will ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. A set of budget crosswalk tables between the Space Communication Services and Mission Communications Service budget and the consolidated Space Operations program is described in the <u>Special Issues</u> section.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE NETWORK

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Space Network Services	7,700	4,400	--
TDRS Replenishment Spacecraft	66,700	17,700	--
TDRS Replenishment - Launch Services	30,200	14,000	--
Total	104,600	36,100	--

PROGRAM GOALS

The Space Network program goal is to provide reliable, cost-effective space-based tracking, command and data acquisition telecommunications services to the Human space Flight program, other low-Earth-orbital science missions including observatory-class flights, and selected sub-orbital flight missions. The Space Network program provides for the implementation, maintenance, and operation of the communications systems and facilities necessary to ensure and sustain the high-quality performance of NASA flight operations systems. Replenishment Tracking and Data Relay Satellites (TDRS) and the launch systems required to deploy them are also included in this program.

The Space Network participates in collaborative interagency and international programs, and independently provides communications services to other national and commercial endeavors on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

NASA's Space Network is comprised of a constellation of geosynchronous TDRS and associated dual ground terminals located in White Sands, New Mexico. The current TDRS constellation consists of four fully operational satellites in service (TDRS-4, 5, 6 & 7), and two partially functional spacecraft (TDRS-1 & 3). TDRS-3 is positioned over the Indian Ocean, in conjunction with a remote terminal in Guam, to increase data return from the Compton Gamma Ray Observatory (CGRO), other users and to support Shuttle/International Space Station operations. TDRS-1, now in its sixteenth year, is still providing service to expendable vehicle launches and other peak loads in the eastern network node.

The Goddard Space Flight Center manages the Space Network program, including the TDRS Replenishment Spacecraft program, and the modification and/or system replacement of the ground facilities and equipment as necessary to sustain network operations for current and future missions. The Replenishment Spacecraft program providing three TDRS spacecraft under a fixed-price, commercial practices contract with Hughes Space and Communications Company. The first spacecraft's launch readiness is

scheduled for June 2000. The program provides for spacecraft compatibility modifications to the New Mexico ground terminals. Lockheed Martin Corporation is the prime contractor for launch services for the TDRS Replenishment Spacecraft.

The Lockheed Martin Space Operations Company was recently awarded the Consolidated Space Operations Contract (CSOC) on October 1, 1998, and became the primary support service contractor responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The Space Network provides communication services at data rates up to 300 megabits-per-second (MBPS) using its Ku-band single-access services, data rates of up to three MBPS using its S-band, single-access services, and a low-rate service of up to 150 kilobits-per-second (KBPS) through its multiple-access service. These services provide unparalleled, flexible high-data-rate communications capabilities for flight operations of low-Earth-orbital missions. Customer satellites are provided with command, tracking, and telemetry services via the TDRS spacecraft, which act as relays for commands from and science telemetry return to the ground terminals. The ground terminals are interconnected with flight control, data capture and processing facilities responsible for mission operations.

Communications services are provided to non-NASA customers on a reimbursable basis. A large share of the Space Network Services program that provides for the operations and maintenance of the ground terminal complex is funded with the receipts from reimbursable services. This reimbursable revenue is anticipated to continue and has been taken into account in formulating the NASA FY 2001 budget request.

Space Network services provides the primary communications for orbital operations of the Space Transportation System and its attached payloads. Services are also provided to automated Earth-orbital missions that have communications systems compatible with the TDRS, and can provide nearly continuous high-data-rate services. The Space Network initiated communications services for the International Space Station (ISS) beginning in FY 1999. Services will also be provided on an agreed-to basis to NASA's International partners. Agreements are in place with Japan, the European Space Agency, and Canada. Negotiations are continuing with the Russian Space Agency as a participant for potential cooperative endeavors in telecommunications.

In addition to the day-to-day operations of the Space Network satellites and ground terminals, the program provides for the replenishment of the satellite assets.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Number of hours of network service (thousands)	54,100	57,800	62,000	62,000	--
Number of Space Shuttle Launches supported	6	4	8	6	[9]

The initiation of the ISS assembly and the launches of Terra and Landsat-7 necessitated an increased level of communication services in FY 1999. In FY 2000, full-up support to the ISS will necessitate further increases in the level of communication services.

TDRS Replenishment Spacecraft

Pre-Environmental Review for TDRS-I Plan: March 1999 Actual: May 1999	Verification that the spacecraft is ready for system level environmental testing. Pre-environmental reviews were rephased due to a number of unit level problems on TDRS H, the uniqueness of the TDRS-H payload, and the first-time use of electronic ground test software on TDRS H.
Pre-Environmental Review for TDRS-J Plan: May 1999 Revised: February 2000	Verification that the spacecraft is ready for system level environmental testing. Pre-environmental reviews were rephased due to a number of unit level problems on TDRS H, the uniqueness of the TDRS-H payload, and the first-time use of electronic ground test software on TDRS H.
Complete Integration and Test - TDRS-H Plan: April 1999 Revised: November 1999	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.
Complete Integration and Test – TDRS-I Plan: June 1999 Revised: March 2000	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.
Complete Integration and Test – TDRS-J Plan: August 1999 Revised: May 2000	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.
Launch TDRS-H Plan: 3rd Qtr FY 2000	Launch within five years of contract award will be performed, ensuring the continuity of TDRSS services to user space flight systems. Launch of TDRS-I and TDRS-J is now scheduled for 2002 and 2003.

CONSOLIDATED SPACE OPERATIONS CONTRACT (CSOC)

Phase 1 Contract Award	May 1997
Phase 2 Proposal due	January 1998
Phase 2 Contract Award	October 1998
Phase 2 Phase-In	October-December 1998
Phase 2 CSOC In Force	January 1999

ACCOMPLISHMENTS AND PLANS

The Space Network is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. In FY 1999, the missions supported included four Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit such as Hubble Space Telescope (HST) and the Compton Gamma Ray Observatory(CGRO), as well as other compatible missions such as Ocean Topography Experiment, Extreme Ultraviolet Explorer (EUVE), Department of Defense customers, the Rossi X-ray Timing Explorer (RXTE), the Starlink research aircraft, Engineering Test Satellite (ETS-VII), Tropical Rainfall Measurement Mission(TRMM), and the Long Duration Balloon program. The Space Network extended service (on a reimbursable basis) to the expendable launch vehicle community including agreements with US Air Force Titan and Lockheed Martin's commercial Atlas programs.

In FY 1999 and FY 2000, the Space Network continued to provide services to the Space Shuttle Flights and their attached payloads as well as the construction phase of the International Space Station, LANDSAT-7, and the Terra mission.

In FY 1999, work began on the TDRS low power transceiver (LPT) development. This initiative seeks to provide a lower cost, lighter weight and lower power-demanding alternative to today's expensive transponder options for spacecraft telemetry, command, and orbit determination requirements. The multiple-mode nature of the LPT allows for flexible multiple-frequency implementations that also provide for Global Positioning System (GPS) position processing including time determination. Suggested applications include use on smaller satellites, satellite crosslinks and NASA/DOD network interoperability. This effort will continue into FY 2000 with the delivery of a prototype unit and the initiation of flight unit development; completed flight units are planned to be delivered in FY 2001.

Work will begin in FY 2000 on various components of the DAS, including the Third Generation Beam Forming System (TGBFS). The TGBFS development activity was initiated to augment the TDRSS multiple-access (MA) capability and to permit customers to implement new operations concepts incorporating continuous return link communications. The DAS will expand existing Multiple Access (MA) return service capabilities by allowing customers to directly obtain services from the Space Network without scheduling through the Network Control Center (NCC). The TGBFS component is planned to be completed in FY 2001. The DAS will be installed at White Sands, New Mexico, and is expected to be operational and available for customer use in FY 2002.

Space Network ground terminal modifications in support of the TDRS replenishment project were completed at White Sands Complex in FY 1999. Development f the White Sands Alternate Resource Terminal (WART) was initiated. The WART will support National Science Foundation activities in the Antarctic. This system is planned to become operational in FY 2000.

Development activities for the TDRS Replenishment Spacecraft program continue to progress. Integration activities associated with TDRS-H were completed and the spacecraft underwent environmental testing. TDRS-I and TDRS-J spacecraft manufacturing, integration, and testing activities continue. Modifications and testing of the ground systems were completed at the White Sands Complex in preparation for TDRS-H on-orbit checkout and operations.

In FY 2000, all integration activities on TDRS-H will be completed. Launch readiness is planned for June 2000. On-orbit testing and acceptance of the TDRS-H spacecraft will be completed. Modifications to the ground terminal will undergo final acceptance after the launch of TDRS-H. The TDRS-I spacecraft will have completed integration and testing activities. TDRS-I will undergo a pre-storage review and the contractual option to store the spacecraft will be exercised. The TDRS-J spacecraft will have completed all environmental test activities and initiate final functional test activities.

BASIS OF FY 2001 FUNDING REQUIREMENT

NASA INTEGRATED SERVICES NETWORK (NISN)

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
NASA Integrated Services Network	81,200	53,600	--

PROGRAM GOALS

The NASA Integrated Services Network (NISN) goal is to provide high-quality, reliable, cost-effective telecommunications systems and services for mission control, science data handling, and program administration for NASA programs. The NISN program provides for the implementation, maintenance, and operation of the telecommunications services, control centers, switching systems, and other equipment necessary to provide an integrated approach to NASA communication requirements.

The NISN supports NASA's programs in collaborative interagency, international, and commercial enterprises. Many collaborative arrangements are performed on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

NISN is a nationwide system of leased voice, video, and data services; leased wide-band terrestrial and satellite circuits; and control centers, switching centers, network equipment and other communications devices. International telecommunications links are also provided to NASA's Deep Space Network (DSN) sites in Australia and Spain; Spaceflight Tracking and Data Network (STDN) sites outside the Continental U.S.; and common telecommunications exchange points that provide interconnectivity to NASA international partners. Administrative, scientific, and mission control exchanges among NASA and its industrial and scientific partners are supported by NISN networks and systems. Support and participation by other U.S. agencies, universities, and research centers, and by other space-faring nations, are also facilitated, including the provision of secure circuits, systems, and facilities. Domestic Telecommunications circuits are primarily leased by NASA under the FTS-2000 contract managed by the General Services Administration; international circuits are leased under separate contractual arrangements. NISN maintains cooperative networking agreements for exchanging services with the European Space Agency (ESA), Canada, Japan, France, and Russia. The Computer Science Corporation and AlliedSignal Technical Services Corporation provide engineering and operations support for the NISN.

The NISN Project Office manages the NISN at the Marshall Space Flight Center in partnership with the Goddard Space Flight Center. NISN provides unique mission and mission support telecommunications services to all NASA Centers, supporting contractor locations, international partners, research institutes, and universities. NASA also provides telecommunications services to non-NASA customers on a reimbursable basis.

Command, telemetry, and voice systems communications are provided between spacecraft mission control facilities, tracking and data acquisition networks, launch sites, NASA data processing centers, and scientific investigators whose support is critical to mission control and command. NISN support NASA aeronautical test sites, as well as preflight verification of NASA spacecraft systems and their interconnectivity with NASA communications systems.

The NISN interconnects NASA installations and national and international aerospace contractors, laboratories, scientific investigators, educational institutions, and other Government installations in support of administrative, science data exchange, and other research and analysis activities. Specific mission support services provided by the NISN are voice and video teleconferencing, broadcast television, computer networking services, as well as data handling and transfer services including Internet connectivity.

NISN provides for the improvement, operation and maintenance of NASA network systems and facilities. Telecommunications network systems include digital voice, data and video switching equipment, audio and video conferencing and bridging systems, wide-band multiplexing equipment, and sophisticated network management, monitoring, and fault isolation systems. Equipment and facilities of NASA Select Television are also provided by the NISN.

Telecommunications services are rapidly developing and maturing. With the advancements of telecommunications technology and standards, NASA telecommunications services are now more readily available from commercial sources. NISN continually analyzes current telecommunications requirements to determine the feasibility of providing NASA telecommunications services through commercial sources. NISN also maintains a close relationship with the NASA Research and Education Network (NREN), NASA's research and development, to determine what information technologies are beneficial to support NASA's growing telecommunications needs. As technologies become standard and commercially available, NISN conducts study and cost analyses to determine the feasibility of purchasing these services for use by the NASA community.

SCHEDULE AND OUTPUTS

	FY 1999		FY 2000		FY 2001
	Plan	Actual	Plan	Current	Plan
Number of locations connected	410	410	420	420	--

ACCOMPLISHMENTS AND PLANS

In FY 1999, NISN will complete the necessary changes for the network resources to be Y2K compliant in December 1998. This will support NASA's goal to be Y2K compliant by February 1999. NISN will continue to support the development of the NGIXs, which will increase NISN's ability to provide enhanced-routed data services to NISN customers such as ISS and EOS. NISN will continue to play an active role in technology assessments, focusing on voice over ATM and IP, QoS prototyping, and routing protocol evaluation. NISN will add additional capacity, network connections, and services as necessary to support the initial implementation of the IFMP, and the growth of the ISS and EOS programs. NISN will complete the migration of services to the new Consolidation Space Operations Contract (CSOC) and the Federal Telecommunications Services - 2001 (FTS2001) contracts.

In FY2000, NISN will continue to analyze commercial services for potential use in meeting NASA's expanding Mission Requirements. NASA will be adding services in support continued implementation of IFMP, CoSMO, ISS Phase II, National Oceanic and Atmospheric Administration (NOAA)-K, Earth Observation System, Advanced Composition Explorer (ACE), Advanced Earth Observing Satellite (ADEOS) and TRMM.

NASA Integrated Services Network (NISN) provides for the implementation, maintenance, and operation of the telecommunications services, control centers, switching systems, and other equipment necessary to provide an integrated approach to NASA communications requirements. NISN completed the transition of the NISN Video Teleconferencing Service to the General Services Administration's Federal Telecommunications Services (FTS) 2000 Switched Compressed Video Transmission Service (SCVTS). This video service is shared by several government agencies, provides connectivity to commercial video services such as those provided by Sprint and MCI, and is also compatible to desktop video systems. This transition standardizes NASA video teleconferencing service on the industry standard of voice activated switching, and provides greater access to non-NASA video systems.

NISN completed the transition of its transmission infrastructure for mission support routed data services to an Asynchronous Transfer Mode (ATM) infrastructure, provided by FTS2000 Network B vendor- Sprint. NISN has also expanded the use of this network from the originally planned eight locations to ten NASA locations. NISN and NASA Research and Education Network (NREN) continue to share these services, resulting in lower network infrastructure costs for NASA as a whole. In addition to commercialization of the transmission, NISN began several studies to strengthen its peering relationships at common network access points, such as the Chicago Network Access Point (NAP) and the Sprint NAP. These are in addition to existing connectivity to internet exchange points on both the west and east coast. These additional connections have increased NISN's access to other government and education locations. NISN is also participating in the development of the Next Generation Internet Exchange (NGIX) sites in conjunction with the Department of Defense, Department of Energy, and the industry provided Abilene network. This will allow network connectivity to many NASA partners without the installation of dedicated services. These peering relationships will greatly benefit the distribution of the Earth Observing System (EOS) data as well as provide connectivity to many of the ISS principle investigators. In FY 2000, NISN will continue to analyze commercial services for potential use in meeting NASA's expanding mission requirements.

MISSION SUPPORT

FY 2001 ESTIMATES

RESEARCH AND PROGRAM MANAGEMENT

PROGRAM GOALS

The primary goal of this budget segment is to acquire and maintain a civil service workforce which reflects the cultural diversity of the Nation and, along with the infrastructure, is sized and skilled consistent with accomplishing NASA's research, development, and operational missions with innovation, excellence, and efficiency. The budget proposed is constructed to achieve that goal.

STRATEGY FOR ACHIEVING GOALS

This civil service workforce is the underpinning for the successful accomplishment of the Nation's civil aeronautics and space programs. These are the people who plan the programs; conduct and oversee the research; select and monitor the contractors; manage the various research, development, and test activities; and oversee all of NASA's operations. A key dimension of the reinvention of NASA has been the restructuring of the civil service workforce to deliver a space and aeronautics program that is balanced, relevant, and at the forefront of technology development.

From FY 1993 to FY 1999, the Agency has been among the "leaders" throughout the executive branch in reducing its civil service workforce by over 6,600. This represents more than a 26 percent reduction. Due to various concerns raised to senior management (primarily safety and reduced staffing in mission critical areas) that we had gone too far too fast in our reductions based on the Zero Based Review (ZBR). NASA initiated a Core Capabilities review to re-assess our workforce needs. The results of this review recommended increasing the workforce at the Human Space Flight centers and Headquarters and stabilizing the NASA workforce throughout the rest of the Agency. These increases at the Human Space Flight centers and Headquarters will begin in FY 2000 and are necessary to strengthen management oversight, program management, and to ensure Shuttle safety and the successful integration of the Space Station. This will result in increased staffing levels in FY 2000 and again in FY 2001. The remaining NASA centers, that have reached the targets associated with the Strategic plan, Centers of Excellence, and Lead Center roles defined over the past several years, will maintain these staff levels and continue to replenish and rebalance skills drained during downsizing.

The Research and Program Management (R&PM) program provides the salaries, other personnel and related costs, travel and the necessary support for all of NASA's administrative functions and other basic services in support of research and development activities at NASA installations. The salaries, benefits, and supporting costs of this workforce comprise approximately 78% of the requested funding. Administrative and other support is 20% of the requests. The remaining 2% of the request is required to fund travel necessary to manage NASA and its programs.

ACCOMPLISHMENTS & PROPOSED RESULTS

NASA has once again achieved its full-time (FTE) targets included in the NASA Workforce Restructuring plan for FY 1999 ahead of schedule. The agency continued to make progress towards specific workforce goals established by the National Performance Review (NPR). These goals were met ahead of schedule through implementation of a restrictive hiring policy and buyouts conducted in FY 1999. The successful buyout used in FY 1999 resulted in more than 300 voluntary losses. The agency used only 18,278 FTE compared to its original plan of 18,545.

The Agency also successfully met the other goals for FY 1999 established as part of the NPR:

- The supervisory span of control has gone from 1:5 in FY 1993 to 1:10 in FY 1999.
- Efforts to reduce specific administrative positions continue on target
- Headquarters employment has been reduced by more than 1,140 from FY 1993

The FY 2001 budget estimate of $2,290.6 million for Research and Program Management represents an increase to the aggressive downsizing levels NASA has proposed since FY 1993. The requested funding level for FY 2001 is an increase of $73.0 million from the FY 2000 budget plan of $1,217.6 million. Of this total increase, Personnel and related costs increase by $97.3 million from FY 2000 to FY 2001. These increases fully fund the civil service workforce, an increase of 328 FTE's from the expected FY 2000 level of 18,413, the full year cost of the 2000 payraise, the payraise projected to be effective in January, 2001 and normal salary growth. Travel represents a slight increase of $1.5 million over the FY 2000 budget plan due to increased requirements for Space Station. Research Operations Support decreases by $25.8 million from the FY 2000 budget plan due to transfers out of ROS into the Rocket Propulsion Testing program and Construction of Facilities (CofF) coupled with the FY 2000 rescission offset by a slight increase for Headquarters Operations.

In summary, the FY 2001 budget requirement of $2,290.6 million will provide for 18,741 FTE civil service workyears to support the activities at nine NASA Installations and Headquarters.

The following describes, in detail, the cost elements within this program.

I. Personnel and Related Costs

A. Compensation and Benefits

1. Compensation

a. Permanent Positions: This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest portion of this functional category.

b. Other Than Full-Time Permanent Positions: This category includes the salaries of NASA's non-permanent workforce. Programs such as Presidential Management Interns, students participating in cooperative training, summer employment, youth opportunity, and temporary clerical support are covered in this category.

c. Reimbursable Detailees: In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

d. Overtime and Other Compensation: Overtime, holiday, post and night differential, and hazardous duty pay are included in this category. Also included are incentive awards for outstanding achievement and superior performance.

2. Benefits: In addition to compensation, NASA, as authorized and required by law, makes the employer's contribution to personnel benefits. These benefits include contributions to the Civil Service Retirement Fund, the Federal Employees Retirement System, employees' life and health insurance, payments to the Medicare fund for permanent employees, and social security contributions. Payments to the civil service retirement fund for re-employed annuitants and severance pay to former employees involuntarily separated through no fault of their own are also included.

B. Supporting Costs

1. Transfer of Personnel: Provided under this category are relocation costs required by law, such as the expenses of selling and buying a home, subsistence expenses, and the movement and storage of household goods.

2. Investigative Services: The Office of Personnel Management is reimbursed for activities such as security investigations of new hires and revalidation of sensitive position clearances, recruitment advertising, personnel studies and Federal wage system surveys.

3. Personnel Training: Training is provided within the framework of the Government Employees Training Act of 1958. Part of the training costs is for courses offered by other Government agencies, and the remainder is for training through nongovernment sources.

II. Travel

A. Program Travel: The largest part of travel is for direction, coordination, and management of program activities including international programs and activities. The complexity of the programs and the geographical distribution of NASA Installations and contractors necessitate this category of travel. As projects reach the flight stage, support

is required for prelaunch activities including overseas travel to launch and tracking sites. The amount of travel required for flight projects is significant as it is directly related to the number of systems and subsystems, the number of design reviews, and the number and complexity of the launches and associated ground operations.

B. Scientific and Technical Development Travel: Travel to scientific and technical meetings and seminars permits employees engaged in research and development to participate in both Government sponsored and nongovernment sponsored activities. This participation allows personnel to benefit from exposure to technological advances, which arise outside NASA, as well as allowing personnel to present both accomplishments and problems to their associates and provides for the dissemination of technical results to the United States community.

C. Management and Operations Travel: Management and operations travel provides for the direction and coordination of general management matters and travel by officials to review the status of programs. It also includes travel by functional managers in such areas as personnel, financial management, and procurement. This category also includes the cost of travel of unpaid members of research advisory committees; and initial duty station, permanent change of assignment, and related travel expenses.

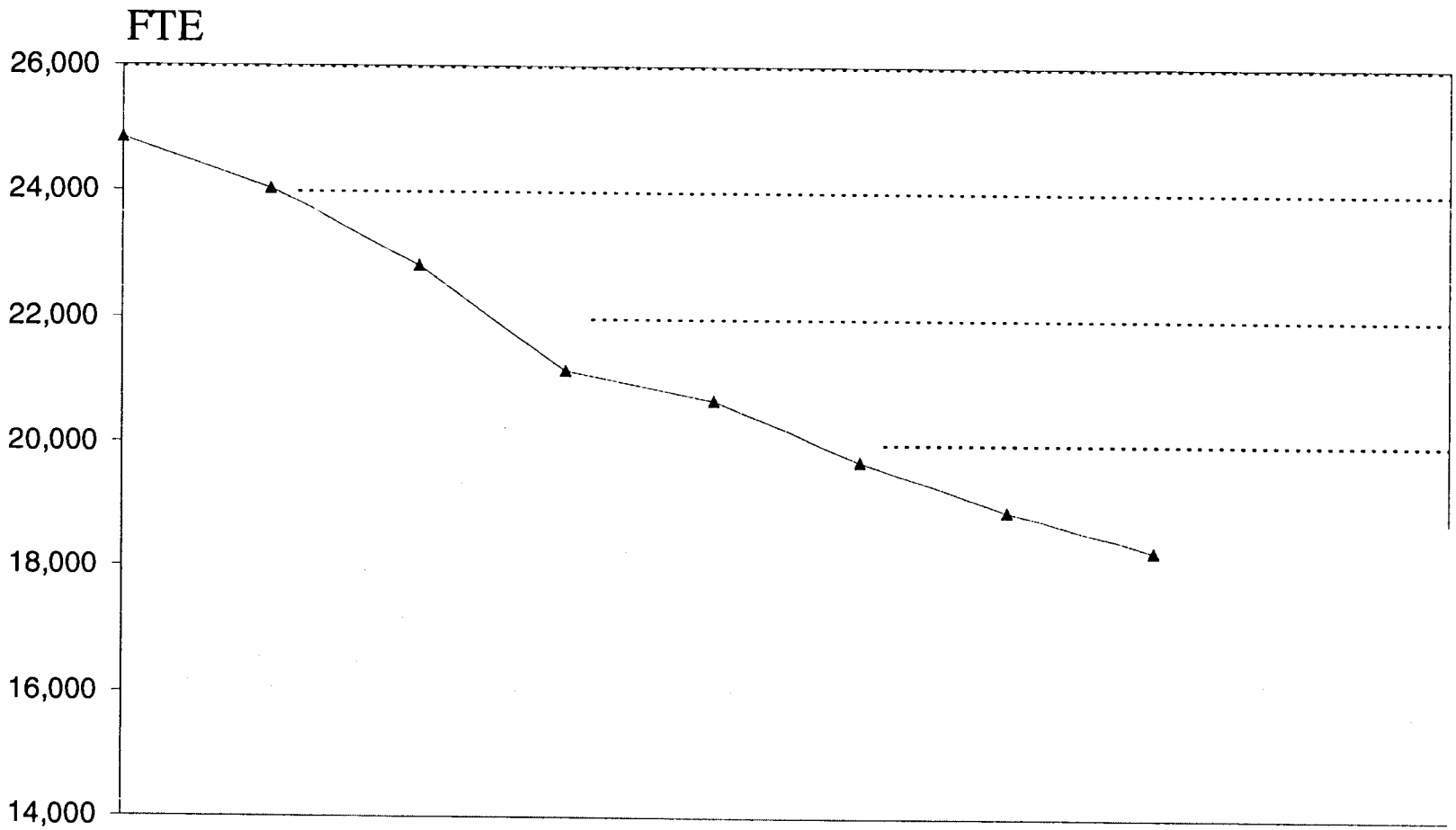
III. Research Operations Support

A. Facilities Services: Facilities Services provides basic security, fire protection, and other custodial services. It also provides maintenance of roads and grounds and of all administrative buildings and facilities. Finally, it provides rental of administrative buildings and all utility costs of administrative buildings.

B. Technical Services: Technical Services provides the Administrative Automatic Data Processing capability that supports Accounting, Payroll, Budgeting, Procurement, and Personnel as well as all the other Administrative functions. It also funds the Graphics and Photographic support to these functions. Finally, it funds the Installation-wide safety and public information programs.

C. Management and Operations: Management and Operations funds the telephone, mail, and logistics systems, the administrative equipment and supplies, and the transportation system including the general purpose motor pools and the program support aircraft. It also funds the basic medical and environmental health programs. Finally, it funds printing and reproduction and all other support, such as small contract and purchases for the Center Directors staff and the Administrative functions.

NASA FTE Civil Service Reduction Plan



	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01
FTE Limit	24,731	23,623	23,075	21,555	20,501	19,364	18,545	18,413	18,741

Does not include the NASA Office of Inspector General

SUMMARY OF BUDGET PLAN BY FUNCTION
(Thousands of Dollars)

	FY 1999 OPLAN 12/23/1999	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
PERSONNEL AND RELATED COSTS	$1,598,600	$1,683,100	$1,780,400
TRAVEL	$47,800	$51,700	$53,200
RESEARCH OPERATIONS SUPPORT	$463,200	$482,824	$457,000
TOTAL PROGRAM PLAN	**$2,109,600**	**$2,217,624**	**$2,290,600**

DETAIL OF BUDGET PLAN BY FUNCTION
(Thousands of Dollars)

	FY 1999	FY 2000	FY 2001
I. Personnel and related costs	$1,598,600	$1,683,100	$1,780,400
A. Compensation and benefits	$1,542,600	$1,624,300	$1,728,500
1. Compensation	$1,266,700	$1,339,800	$1,419,800
2. Benefits	$275,900	$284,500	$308,700
B. Supporting costs	$56,000	$58,800	$51,900
1. Transfer of personnel	$7,900	$13,200	$7,400
2. Investigative services	$2,200	$3,600	$2,100
3. Personnel training	$45,900	$42,000	$42,400
II. Travel	$47,800	$51,700	$53,200
A. Program travel	$30,000	$32,100	$32,600
B. Scientific and technical development travel	$6,000	$6,800	$7,000
C. Management and operations travel	$11,800	$12,800	$13,600
III. Research operations support	$463,200	$482,824	$457,000
A. Facilities services	$130,100	$130,224	$121,500
B. Technical services	$193,300	$211,100	$190,000
C. Management and operations	$139,800	$141,500	$145,500
Total	$2,109,600	$2,217,624	$2,290,600

DISTRIBUTION OF BUDGET PLAN BY FUNCTION BY INSTALLATION
(Thousands of Dollars)

FUNCTION	TOTAL NASA	JSC	KSC	MSFC	SSC	GSFC	ARC	DFRC	LARC	GRC	HQS
PERSONNEL AND RELATED COSTS											
FY 1999	1,598,600	285,200	150,400	227,800	20,000	274,000	138,700	49,600	184,800	163,200	104,900
FY 2000	1,683,100	291,400	160,000	236,100	22,600	285,300	141,600	53,100	198,500	170,400	124,100
FY 2001	1,780,400	308,600	167,300	250,900	24,200	298,700	153,000	57,300	209,300	179,200	131,900
TRAVEL											
FY 1999	47,800	8,800	4,300	6,600	600	7,500	3,300	1,600	4,700	3,700	6,700
FY 2000	51,700	8,800	5,300	6,100	700	7,300	3,500	1,400	4,400	3,500	10,700
FY 2001	53,200	8,800	5,300	6,100	700	7,300	3,500	1,400	4,500	3,800	11,800
RESEARCH OPERATIONS SUPPORT											
FY 1999	463,200	40,600	91,600	53,400	20,700	52,500	28,900	5,500	24,900	27,100	118,000
FY 2000	482,824	39,900	90,000	52,754	22,100	56,600	28,929	4,423	19,994	24,700	143,424
FY 2001	457,000	44,500	75,500	53,500	18,400	61,700	30,300	3,000	26,600	22,600	120,900
TOTAL											
FY 1999	2,109,600	334,600	246,300	287,800	41,300	334,000	170,900	56,700	214,400	194,000	229,600
FY 2000	2,217,624	340,100	255,300	294,954	45,400	349,200	174,029	58,923	222,894	198,600	278,224
FY 2001	2,290,600	361,900	248,100	310,500	43,300	367,700	186,800	61,700	240,400	205,600	264,600

SUMMARY OF BUDGET PLAN BY INSTALLATION
(Thousands of Dollars)

	FY 1999	FY 2000	FY 2001
JOHNSON SPACE CENTER	$334,600	$340,100	$361,900
KENNEDY SPACE CENTER	$246,300	$255,300	$248,100
MARSHALL SPACE FLIGHT CENTER	$287,800	$294,954	$310,500
STENNIS SPACE CENTER	$41,300	$45,400	$43,300
AMES RESEARCH CENTER	$170,900	$174,029	$186,800
DRYDEN FLIGHT RESEARCH CENTER	$56,700	$58,923	$61,700
LANGLEY RESEARCH CENTER	$214,400	$222,894	$240,400
GLENN RESEARCH CENTER	$194,000	$198,600	$205,600
GODDARD SPACE FLIGHT CENTER	$334,000	$349,200	$367,700
HEADQUARTERS	$229,600	$278,224	$264,600
AGENCY TOTAL	$2,109,600	$2,217,624	$2,290,600

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY INSTALLATION

	FY 1999	FY 2000	FY 2001
Johnson Space Center	3,040	2,926	3,030
Kennedy Space Center	1,759	1,806	1,825
Marshall Space Flight Center	2,653	2,651	2,758
Stennis Space Center	252	272	280
Goddard Space Flight Center	3,263	3,282	3,282
Ames Research Center	1,460	1,457	1,486
Dryden Flight Research Center	597	634	634
Langley Research Center	2,328	2,382	2,387
Glenn Research Center	1,991	1,983	1,972
Headquarters	935	1,020	1,087
Total, full-time equivalents	**18,278**	**18,413**	**18,741**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**1,846**	**1,751**	**1,708**
Major Development Programs	363	285	232
Payloads Program	73	43	39
Explorer Program	225	208	181
Mars Surveyor Program	41	49	47
Discovery Program	15	14	17
Operating Missions	79	83	81
Research and Technology	1,050	1,069	1,111
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**5,364**	**5,294**	**5,627**
International Space Station	2,136	2,385	2,328
Space Operations (SOMO)	358	281	271
Space Flight Operations (Space Shuttle)	1,819	1,754	2,017
Payload & ELV	274	304	353
Life & Microgravity Sciences & Apps	420	481	498
Investment - HEDS	357	89	160
EARTH SCIENCE	**1,365**	**1,382**	**1,419**
Earth Observing System Program	512	593	689
Earth Probes Program	110	121	73
Operating Missions	34	32	30
Research and Technology	622	554	546
ES Reimbursable Activities	87	82	81
AERO-SPACE TECHNOLOGY	**4,227**	**4,227**	**4,414**
Aero-space Focused Programs	945	1,218	1,408
High Speed Research Program	273	3	1
Advanced Subsonics Tech Program	298	51	94
Aero-Space Base	2,405	2,672	2,630
Commercial Technology Program	215	191	190
Investment - AST	91	92	91
PROGRAM OPERATIONS	**5,476**	**5,759**	**5,573**
Corporate Programs	210	240	232
Corporate Operations	1,052	1,140	1,207
Center Operations	4,214	4,379	4,134
Total full-time equivalents	**18,278**	**18,413**	**18,741**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

LYNDON B. JOHNSON SPACE CENTER

ROLES AND MISSIONS

SPACE STATION - The Johnson Space Center (JSC) has lead center management responsibility for the International Space Station program. In addition, specific JSC technical responsibilities include development of a set of facilities and systems to conduct the operations of the Space Station including on-orbit control of the Space Station.

The Center also provides institutional personnel as well as engineering and testbed support to the Space Station program. This includes test capabilities, the provision of Government Furnished Equipment (GFE), and engineering analysis support for the work of the prime contractor, its major subcontractors, and NASA system engineering and integration efforts.

SPACE SHUTTLE - JSC has lead center management responsibility for the Space Shuttle. In addition, JSC will provide development, integration, and operations support for the Mission Control Center (MCC), the Shuttle Mission Simulator (SMS), and other ground facilities needed for Space Shuttle Operations. JSC will provide Space Shuttle operational flight program management including system integration, crew equipment modification and processing, crew training, flight mission planning and operations, and procurement of Orbiter hardware.

PAYLOAD AND UTILIZATION OPERATIONS - JSC will also conduct concept studies and development on flight systems and options for human transportation. JSC provides support to the engineering and technical base, payload operations and support equipment, and technology program support.

SPACE SCIENCE - The Center will support the Agency's planetary science program in the area of geosciences required to support future programs, provide curatorial support for lunar materials, assist in information dissemination, and interact with outside scientists. This research focuses on the composition, structures, and evolutionary histories of the solid bodies of the universe.

LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS - JSC is the Lead Center for the following programs/functions; Biomedical Research and Countermeasures; Advanced Human Support Technologies; and Space Medicine. It also has a supporting role in the Microgravity Research program in biotechnology. As part of these activities, JSC will evaluate human physiological changes associated with the space flight environment and develop effective countermeasures to assure crew health and optimal performance during all phases of flight. Protection of flight crew members from the hazards of space radiation is one of NASA's highest priorities. A strategic plan for Space Radiation Health has been developed to acquire the

knowledge necessary to predict radiation risks in space and to develop countermeasures that include advances at the cutting edge of modern technology. JSC will also define and develop on-board health care systems and environmental monitoring systems; crew medical training; ground-based medical support of missions; develop a longitudinal crew health data base; and develop medical and psychological crew selection criteria. The JSC has established a center for the support of biotechnology applications in Microgravity in order to study growth factors, medical chemo/immunotherapeutic, and human tissue transplantation. The Center will integrate life science flight experiments for Spacehab and the ISS; operate integrated payload systems; and train mission specialists in the science aspects of their missions.

MISSION/SPACE COMMUNICATION SERVICES - The Space Operations Management Office (SOMO), manages the telecommunication, data processing, mission operation, and mission planning services needed to ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. The SOMO also provides the administration and management of the Consolidated Space Operations Contract (CSOC).

CENTER MANAGEMENT AND OPERATIONS - Provides management, administrative, and financial oversight of NASA programmatic elements under JSC cognizance. In addition, the center provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
JOHNSON SPACE CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**30**	**40**	**36**
Major Development Programs	0	0	0
Mars Surveyor Program	0	6	3
Discovery Program	2	3	3
Operating Missions	1	1	1
Research and Technology	27	30	29
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**2,112**	**1,994**	**2,080**
International Space Station	883	1,013	1,021
Space Operations (SOMO)	31	29	30
Space Flight Operations (Space Shuttle)	841	834	905
Life & Microgravity Sciences & Apps	98	87	89
Investment - HEDS	259	31	35
AERO-SPACE TECHNOLOGY	**23**	**25**	**24**
Aero-Space Focused Programs	2	1	0
Aero-Space Base	5	8	8
Commercial Technology Program	16	16	16
PROGRAM OPERATIONS	**875**	**867**	**890**
Corporate Programs	15	18	24
Corporate Operations	9	9	9
Center Operations	851	840	857
Total full-time equivalents	**3,040**	**2,926**	**3,030**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

JOHN F. KENNEDY SPACE CENTER

ROLES AND MISSIONS

SPACE STATION - The Kennedy Space Center (KSC) is a supporting center for the Space Station Program. The KSC has developed a set of facilities, systems, and capabilities to conduct the operations of the Space Station. KSC develops launch site operations capabilities for conducting pre-launch and post-landing ground operations including integrated testing, interface verification, servicing, launch activities, and experiment-to rack physical integration. The KSC provides launch site logistics support, resupply and customer utilization. The KSC serves as the primary agent for management and integration of ground processes for all U.S. launched International Space Station (ISS) elements from manufacture and assembly through verification and launch. The KSC develops and maintains ISS flight systems expertise to support the ISS on-orbit mission and retains technical and operational experience within NASA and KSC for ground processing and verification of space flight hardware for follow-on programs.

SPACE SHUTTLE - KSC will provide Space Shuttle launch preparation, including orbiter processing, and Ground Support Equipment (GSE) logistics; and operation and maintenance of GSE.

PAYLOAD CARRIERS AND SUPPORT - KSC is the Lead Center for the Payload Carriers and Support Program. KSC provides technical expertise, facilities and capabilities to perform payload buildup, test and checkout, integration and servicing of multiple payloads; development, operation, logistics and maintenance of Ground Support Equipment; transportation of payloads and supporting equipment to the Space Shuttle; and integration and installation of the payloads into the Space Shuttle. The KSC develops, activates, operates and maintains the Payload Carrier facility system, GSE, and processes to enable efficient launch site processing of carriers and payloads.

EXPENDABLE LAUNCH VEHICLES - KSC will provide government insight/oversight of all launch vehicle and payload processing and checkout activities for all NASA contracted expendable launch vehicle and upper stage launch services both at KSC and the Vandenburg Air Force Base.

CENTER MANAGEMENT AND OPERATIONS - KSC will provide administrative and financial services in support of Center management and will provide for the operation and maintenance of the institutional facilities, systems, laboratories, test beds, associated technical infrastructure, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
KENNEDY SPACE CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**1,246**	**1,173**	**1,304**
International Space Station	346	321	328
Space Flight Operations (Space Shuttle)	630	563	657
Payload & ELV Support	206	236	269
Life & Microgravity Sciences & Apps	16	15	16
Investment - HEDS	48	38	34
AERO-SPACE TECHNOLOGY	**33**	**48**	**37**
Aero-Space Focused Programs	15	30	21
Commercial Technology Program	18	18	16
PROGRAM OPERATIONS	**480**	**585**	**484**
Corporate Programs	29	31	31
Center Operations	451	554	453
Total full-time equivalents	**1,759**	**1,806**	**1,825**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

GEORGE C. MARSHALL SPACE FLIGHT CENTER

ROLES AND MISSIONS

SPACE STATION - The center will provide engineering support to the program including engineering analysis in support of the International Space Station (ISS) system engineering and integration effort and will provide the lead for the design and development of the ISS Environmental Control and Life Support System (ECLSS) and the ISS Propulsion Module. In addition, the center has oversight responsibility for the development of the Nodes 1 & 2, Multi Purpose Logistics Module and Interim Control Module as well as design integration of cargo elements for flight on the MSFC provided unpressurized logistics carrier to support ISS mission build and logistics supply flights. MSFC also has responsibility for developing payload utilization capabilities and planning and executing payload integration and operations activities. This includes the development and operation of the EXPRESS Rack payload carrier, the Payload Operations Integration Center, ISS Payload Data Services System and the ISS Payload Planning System. MSFC's Lead Center Microgravity Research responsibilities include managing the development of major facilities to be permanently housed on the ISS which include the Materials Science Research Facility, Biotechnology Facility, Fluids and Combustion Facility, Low Temperature Microgravity Physics Facility, and Microgravity Science Glovebox.

SPACE SHUTTLE – The Space Shuttle Projects Office (SSPO) is responsible for executing the Space Shuttle Program role assigned to MSFC. These responsibilities include activities associated with the Space Shuttle Main Engine (SSME), External Tank (ET), Solid Rocket Booster (SRB), and Reusable Solid Rocket Motor (RSRM). The SSPO is responsible for these propulsion hardware elements and associated systems, test and flight operations, and facilities.

SPACE SCIENCE – The Science Directorate at MSFC will foster the generation and communication of knowledge relative to Space Science. As the NASA lead center for Chandra development and operations, following it's successful launch and deployment on July 23, 1999, MSFC continues to lead the on-orbit science operations phase. MSFC will also continue leading the Relativity Mission (Gravity Probe-B) as well as management of other selected payloads. Leading the Agency in Space Optics Manufacturing and Technology, MSFC will develop ultra lightweight large-aperture optics and optical technology for space applications, providing world class facilities and capabilities for optics fabrication, metrology, and testing that will benefit NASA, other government agencies, academia, and industry. In addition, MSFC oversees the National Center for Space Science and Technology, in cooperation with other government agencies, academia, and industry to aid in the development of products that benefit humankind.

LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS - As NASA's Lead Center for Microgravity Research, MSFC will manage and provide the fundamental science and technology for processing materials under conditions that allow detailed

examination of the constraints imposed by gravitational forces. MSFC will perform research in the areas of crystal growth, fluid physics, biophysics, solidification mechanics, and polymeric materials. The Center will define and develop hardware apparatus for Microgravity research, and perform and manage research objectives, implementation, and applications to advance knowledge and strengthen the foundations for continuing the exploration and development of space. Also, MSFC is responsible for implementing the Materials Science and Biotechnology Science disciplines, the Glovebox Program, and Space Product Development within the Microgravity Research Program. Furthermore, emphasis will be given to developing and transitioning to the private sector the technology and applications of products developed for space. MSFC's efforts enable scientific and commercial researchers the unique opportunity to use the low-gravity environment of space as a catalyst to generate new knowledge, products, and service that improve the quality of life on earth.

SPACE TRANSPORTATION - The MSFC Space Transportation Directorate is responsible for executing the NASA Lead Center role for the space transportation systems development activities. The Center will consolidate space transportation programs and projects at MSFC and will plan, direct, and execute research, technology maturation, advanced design and development, and sustaining engineering for NASA's space transportation systems, including expendable and reusable launch vehicles, heavy lift vehicles, upper stages, in-space transportation systems, and other associated transportation systems and subsystems. MSFC will integrate program and project level planning, research, and development to ensure a well-balanced space transportation development program that meets the Agency's aggregate needs in a coordinated and integrated manner. The Center will provide propulsion and vehicle technology to reduce the cost and schedule risk in the development of next generation space transportation vehicles. It will develop technology in vehicle and propulsion systems, advanced manufacturing processes, and materials and structures. The Center will conduct technology efforts, under contract including cooperative agreements, with the U.S. launch vehicle industry, to improve the competitiveness of current systems. Specific responsibilities within space transportation include managing the governmental participation in the X-33 Program, a cooperative partnership with industry; Integrating the Future-X Pathfinder Experimental Flight Projects; Managing and integrating propulsion module flight elements for the International Space Station.

EARTH SCIENCE - MSFC is studying the interrelationship of global-scale climate processes and regional-scale hydrology, which is the science of water's distribution and variability over Earth, its integrating role in linking the planet's physical, biogeochemical, and geophysical fluid subsystems, and the associated human dimensions of Earth system variability. Utilizing global observations and information systems, improved and validated predictive models will be developed. MSFC will manage science strategy and implement the process to establish a world class institution focused on research, applications, and education concerning climate change and the water cycle of the Earth systems. MSFC will also lead in the operation of the Global Hydrology and Climate Center.

MISSION/SPACE COMMUNICATION SERVICES - MSFC manages and maintains the NASA Integrated Services Network (NISN) - NISN services provide communications hardware, software, and transmission medium that inter-connects NASA Headquarters, installations, universities, and major contractor locations for the transfer of data, voice, and video.

CENTER MANAGEMENT AND OPERATIONS - MSFC provides administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment. Lead center for the development and implementation of the NASA Automation Consolidation Center (NACC), Agency Consolidated Payroll, Earned Value Performance Management, and Agency Logistics Business Systems Operations and Maintenance.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

MARSHALL SPACE FLIGHT CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**265**	**168**	**149**
Major Development Programs	96	10	7
Operating Missions	4	2	2
Research and Technology	165	156	140
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**1,109**	**1,224**	**1,308**
International Space Station	612	736	702
Space Operations (SOMO)	12	11	11
Space Flight Operations (Space Shuttle)	325	337	435
Payload & ELV	11	11	26
Life & Microgravity Sciences & Apps	102	112	112
Investment - HEDS	47	17	22
EARTH SCIENCE	**98**	**46**	**46**
Earth Observing System Program	6	4	4
Operating Missions	1	0	0
Research and Technology	80	35	35
ES Reimbursable Activities	11	7	7
AERO-SPACE TECHNOLOGY	**526**	**603**	**664**
Aero-Space Focused Programs	371	216	244
Advanced Subsonics Tech Program	0	49	92
Aero-Space Base	112	307	297
Commercial Technology Program	**43**	**31**	**31**
PROGRAM OPERATIONS	**655**	**610**	**591**
Corporate Programs	44	44	26
Corporate Operations	**34**	**34**	**33**
Center Operations	577	532	532
Total full-time equivalents	**2,653**	**2,651**	**2,758**

RSEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

JOHN C. STENNIS SPACE CENTER

ROLES AND MISSIONS

HUMAN SPACE FLIGHT - As the Lead Center for Propulsion Testing, SSC will operate, maintain, and manage a propulsion test capability that includes test facilities at JSC/WSTF, MSFC and GRC/Plum Brook and related systems for development, certification, and acceptance of rocket propulsion systems and components. The Center will provide, maintain and manage the facilities and the related capabilities required for the continued development and acceptance testing of the Space Shuttle Main Engines. SSC will also maintain and support the Center's technical core laboratory and operations to enable SSC to conduct advanced propulsion test technology research and development for government and commercial propulsion programs.

EARTH SCIENCE - Through the Commercial Remote Sensing Program, SSC will enhance U.S. economic competitiveness via commercial partnership programs that apply remote sensing technologies in business applications and reduce new product development costs. As part of the Applied Research and Data Analysis program, SSC will conduct fundamental and applied research which increases our understanding of environmental systems sciences, with emphasis on coastal research of both land and oceans.

AERONAUTICAL RESEARCH AND TECHNOLOGY - Through the Technology Transfer and Small Business Innovative Research programs, SSC will broaden and accelerate the development of spin-off technologies derived from national investments in aerospace research. SSC will also support the development of new and innovative propulsion technologies through the Advanced Space Transportation Program that supports the agency goal of reducing the cost of access to space.

CENTER MANAGEMENT AND OPERATIONS – SSC provides administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment. The Center will provide, operate, maintain, and manage the institutional base and laboratories required to support NASA programs, Commercial programs and other Federal and State agencies and organizations resident at the SSC.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

STENNIS SPACE CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**15**	**15**	**81**
Space Flight Operations (Space Shuttle)	12	12	12
Investment - HEDS	3	3	69
EARTH SCIENCE	**26**	**26**	**26**
Research and Technology	26	26	26
AERO-SPACE TECHNOLOGY	**44**	**22**	**35**
Aero-Space Focused Programs	33	16	20
Advanced Subsonics Tech Program	0	0	0
Aero-Space Base	8	3	12
Commercial Technology Program	3	3	3
PROGRAM OPERATIONS	**167**	**209**	**138**
Corporate Programs	16	26	33
Center Operations	151	183	105
Total full-time equivalents	**252**	**272**	**280**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

GODDARD SPACE FLIGHT CENTER

ROLES AND MISSIONS

SPACE SHUTTLE/PAYLOAD AND UTILIZATION OPERATIONS - GSFC manages flights of the Hitchhiker, a reusable carrier system which provides increased flight opportunities with reduced leadtime while maximizing Space Shuttle load factors and minimizing spaceflight costs. GSFC also manages and coordinates the Agency's Get Away Special (GAS) program.

SPACE SCIENCE - GSFC manages physics and astronomy activities in the following discipline areas: gamma ray astronomy, X-ray astronomy, ultraviolet and optical astronomy, infrared and radio astronomy, particle astrophysics, solar physics, interplanetary physics, planetary magnetospheres, and astrochemistry. GSFC is also responsible for conducting the mission operations for a variety of operating spacecraft. Other activities include managing NASA's sounding rocket and scientific balloon program.

GSFC also conducts planetary exploration research into the physics of interplanetary and planetary space environments. Participates in planetary mission instrument development, operations, and data analysis. GSFC develops technologies targeted at improved spaceborne instruments, and on-board spacecraft systems and subsystems.

EARTH SCIENCE - Lead Center for Earth Science, including the Earth Observing System (EOS). The primary objective of the EOS is to record global change and to observe regional-to-global processes. The EOS will document global change over a fifteen year period to provide long-term, consistent data sets for use in modeling and understanding global processes. This process and modeling research effort will provide the basis for establishing predictive global change models for policy makers and scientists.

Manages Earth Probes and New Millennium flight projects; manages, on a reimbursable basis, the acquisition of meteorological observing spacecraft for the National Oceanic and Atmospheric Administration (NOAA). Conducts science correlation measurements from balloons, sounding rockets, aircraft, and ground installations.

AERONAUTICAL RESEARCH AND TECHNOLOGY - The Wallops Flight Facility provides institutional and technical support to Langley Research Center, other NASA centers, and commercial users who conduct flight studies of new approach and landing procedures using the latest in guidance equipment and techniques, pilot information displays, human factors data, and terminal area navigation. As an integral partner in the Agency's High Performance Computing and Communications (HPCC) program, GSFC leads an effort to enhance the infusion of HPCC technologies into the Earth community through the

provision of advanced computer architectures and communication technologies. Promotes private sector investment in space-based technologies through the transfer of technologies that derive from NASA's programs and activities.

MISSION/SPACE COMMUNICATION SERVICES - Research and technology involves the investigation and development of advanced systems and techniques for spacecraft communications and tracking, command and control, and data acquisition and processing. The primary objectives are to apply technology and develop advanced capabilities to meet the tracking and data processing requirements of new missions and to improve the cost effectiveness and reliability of flight mission support.

Although the Johnson Space Center is designated as the Space Operations Lead Center, GSFC manages a number of critical program elements, including operation of the Tracking and Data Relay Satellite System (TDRSS); the development of the replenishment TDRSS spacecraft; mission control, data processing, and orbit/attitude computation support; operating the Space Tracking and Data Network (STDN), the NASA Communications (NASCOM) Network, and the Aeronautics, Balloons and Sounding Rocket Program.

The NASCOM Network links the stations of the Deep Space Network (DSN), STDN, TDRSS, and other tracking and data acquisition elements with control centers and data processing and computation centers.

CENTER MANAGEMENT AND OPERATIONS - Provides administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GODDARD SPACE FLIGHT CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**1,010**	**1,013**	**990**
Major Development Programs	193	201	167
Payloads Program	73	43	39
Explorer Program	221	204	177
Mars Surveyor Program	4	3	2
Discovery Program	4	4	6
Operating Missions	69	75	78
Research and Technology	446	483	521
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**307**	**223**	**214**
Space Operations (SOMO)	257	175	166
Space Flight Operations (Space Shuttle)	4	2	2
Payload & ELV	46	46	46
EARTH SCIENCE	**882**	**940**	**964**
Earth Observing System Program	430	513	607
Earth Probes Program	97	108	58
Operating Missions	32	31	29
Research and Technology	247	213	196
ES Reimbursable Activities	76	75	74
AERO-SPACE TECHNOLOGY	**45**	**48**	**46**
High Speed Research Program	2	3	1
Advanced Subsonics Tech Program	4	2	2
Commercial Technology Program	39	43	43
PROGRAM OPERATIONS	**1,019**	**1,058**	**1,068**
Corporate Programs	33	45	40
Corporate Operations	69	69	70
Center Operations	917	944	958
Total full-time equivalents	**3,263**	**3,282**	**3,282**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

AMES RESEARCH CENTER

ROLES AND MISSIONS

AERO-SPACE TECHNOLOGY – Conduct aeronautics research in ground-based and airborne automation technologies, human factors, and operational methodologies for safe and efficient airspace operations. Perform Agency-wide leadership to conduct research and technology development to enable and foster the intelligent vehicle of the future through the implementation of integrated vehicle health management as a vehicle discipline. Provide high-fidelity flight simulations to support national goals in aviation safety and capacity, as well as vehicle development requirements. Conduct research on advanced thermal protection systems and perform arcjet testing to meet national needs for access to space and planetary exploration. Strengthen basic research and technology development of aircraft, space access vehicles, and space operations. Develop an integrated set of experimental and computational technologies built around an embedded information systems backbone, to provide rapid, accurate vehicle synthesis and testing capabilities. Conduct research spanning computation through flight, for Rotorcraft and Powered Lift configurations and for high performance aircraft, for improved efficiency, affordability, and performance. Emphasize joint research and technology projects with other NASA installations, government agencies, industry and academia. This will be achieved through a balance of Research and Technology Base programs that address fundamental knowledge and long-term opportunities. A series of Focused Technology Programs capitalize on these opportunities with concentrated efforts.

SPACE SCIENCE - Ames has the agency lead role in Astrobiology (the study of life in the universe) which focuses on the origin of life and its possible development on other worlds. Research includes advanced laboratory and computation facilities for astrochemistry; planetary atmosphere modeling, including relationships to the atmosphere of the Earth; the formation of stars and planetary systems; and an infrared technology program to investigate the nature and evolution of astronomical systems. Development continues of the Stratospheric Observatory for Infrared Astronomy (SOFIA) for research to be conducted by various NASA/university teams. Research and development in advanced information technologies are directed toward significantly increasing the efficiency of SOFIA as it becomes operational. Ames is the lead center for information technology efforts in the cross-enterprise spacecraft technology program. In addition, Ames is the lead center for the Intelligent Systems program which provides critical, next-generation information technology capabilities for ongoing NASA missions and activities.

LIFE AND MICROGRAVITY SCIENCE - Ames has the agency lead role in Gravitational Biology and Ecology programs. These synergistic programs examine the adaptation of life forms to reduced gravity. Research continues into the effects of gravity on living systems using spaceflight experiments, ground simulation, and hypergravity facilities to understand how gravity affects the development, structure and functions of living systems. Development continues on the Space Station

Biological Research Project, the key life science facility aboard the International Space Station. Also studied are options for preventing problems in crew health and psychophysiology during and after extended spaceflight. Ames has a primary focus on advanced physical/chemical technologies for life support, including research into all aspects of regenerative life support. Research is conducted in the areas of ecosystems and health monitoring.

EARTH SCIENCE - Ames builds instruments and computer models for the measurement and analysis of atmospheric constituents and properties from aircraft platform are being developed. Applied research and developments to enhance the use of remote and in-situ sensing technology for Earth resources applications continues.

SAFETY AND MISSION ASSURANCE - Provide institutional safety and health programs and develop and integrate Safety and Mission Assurance guidelines into program and project development. Ames has created a Systems Management function to assist programs and projects in their initial development phase to ensure their successful implementation.

CENTER MANAGEMENT AND OPERATIONS - Provide administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems and equipment. Ames recently achieved ISO certification.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
AMES RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**211**	**226**	**241**
Major Development Programs	59	59	55
Mars Surveyor Program	2	5	5
Discovery Program	2	0	0
Research and Technology	148	162	181
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**110**	**122**	**122**
International Space Station	53	65	68
Space Flight Operations (Space Shuttle)	2	2	2
Life & Microgravity Sciences & Apps	55	55	52
EARTH SCIENCE	**40**	**51**	**61**
Earth Observing System Program	1	1	2
Research and Technology	39	50	59
AERO-SPACE TECHNOLOGY	**714**	**671**	**675**
Aero-Space Focused Programs	198	240	235
High Speed Research Program	26	0	0
Advanced Subsonics Tech Program	48	0	0
Aero-Space Base	401	392	401
Commercial Technology Program	17	15	15
Investment - AST	24	24	24
PROGRAM OPERATIONS	**385**	**387**	**387**
Corporate Programs	15	15	16
Corporate Operations	5	8	8
Center Operations	365	364	363
Total full-time equivalents	**1,460**	**1,457**	**1,486**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

DRYDEN FLIGHT RESEARCH CENTER

CENTER ROLES AND MISSIONS

AERO-SPACE TECHNOLOGY - Develop, manage, and maintain facilities and testbed aircraft to support safe, timely, and cost effective NASA flight research and to support industry, university, and other government agency flight programs.

Conceive, formulate, and conduct piloted and unpiloted research programs in disciplinary technology, integrated aeronautical systems, and advanced concepts to meet current and future missions throughout subsonic, supersonic, and hypersonic flight regimes.

Conduct flight research programs in cooperation with other NASA Installations, other government agencies, the aerospace industry, and universities. Transition results, techniques, methods, and tools to industry and government users in a timely manner.

DFRC will also provide flight test support for atmospheric tests of experimental or developmental launch systems, including reusable systems.

INTERNATIONAL SPACE STATION – Conduct technology development and flight test of a prototype emergency Crew Return Vehicle (CRV).

SPACE SHUTTLE /PAYLOAD AND UTILIZATION OPERATIONS - Provide operational and technical support for the conduct of Space Shuttle missions, including on-orbit tracking and communications, landing support of crew and science requirements.

EARTH SCIENCE - Conduct flight operations in support of Airborne Science Missions utilizing aircraft for data collection and observation.

CENTER MANAGEMENT AND OPERATIONS - Provide administrative services in support of Center management and provide for the operation and maintenance of the Institutional facilities, systems and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
DRYDEN FLIGHT RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**51**	**53**	**49**
International Space Station	25	29	25
Space Operations (SOMO)	21	20	20
Space Flight Operations (Space Shuttle)	5	4	4
EARTH SCIENCE	**27**	**27**	**27**
Research and Technology	27	27	27
AERO-SPACE TECHNOLOGY	**399**	**396**	**401**
Aero-Space Focused Programs	59	71	76
Aero-Space Base	326	313	313
Commercial Technology Program	5	3	3
Investment - AST	9	9	9
PROGRAM OPERATIONS	**120**	**158**	**157**
Corporate Programs	13	17	10
Center Operations	107	141	147
Total full-time equivalents	**597**	**634**	**634**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATE

LANGLEY RESEARCH CENTER

CENTER ROLES AND MISSIONS

AERO-SPACE RESEARCH AND TECHNOLOGY - Conduct advanced research in fundamental aerodynamics; high-speed, highly maneuverable aircraft technology; hypersonic propulsion; guidance and controls; acoustics; and structures and materials. Develop a technology base for improving transport, fighter, general aviation, and commuter aircraft. Conduct an aeronautical research and technology program to study current and future technology requirements and to demonstrate technology applications. Conduct theoretical and experimental research in fluid and flight mechanics to determine aerodynamic flows and complex aircraft motions. Conduct research to develop Intelligent Synthesis Environment (ISE) technologies and capabilities that permit the integration of widely distributed science, technology, and engineering teams and that provide advanced tools enabling the teams to create innovative, affordable products rapidly.

Develop innovative new airframe systems to improve safety, reduce emissions and noise to improve environmental compatibility, increase capacity, and reduce cost per seat mile of commercial transport and general aviation aircraft. Conduct control and guidance research programs to advance technology in aircraft guidance and navigation, aircraft control systems, cockpit systems integration and interfacing techniques, and performance validation and verification methods. Conduct research in aircraft noise prediction and abatement. Pioneer the development of new materials, structural concepts, and fabrication technologies to revolutionize the cost, performance, and safety of future aircraft structures for radically new aircraft designs. Provide Agencywide leadership and strategically maintain or increase the agency's preeminent position in structures and materials by serving as the NASA Center of Excellence for Structures and Materials. Conduct aeronautics and space research and technology development for advanced aerospace transportation systems, including hypersonic aircraft, missiles, and space access vehicles using airbreathing and rocket propulsion. Specific technology discipline areas of expertise are aerodynamics, aerothermodynamics, structures, materials, hypersonic propulsion, guidance and controls, and systems analysis. Conduct long-range studies directed at defining the technology requirements for advanced transportation systems and missions. Develop technology options for realization of practical hypersonic and transatmospheric flight.

EARTH SCIENCE - Perform an agency-designated Atmospheric Science mission role in support of the Earth Science Enterprise in the NASA Strategic Plan. As Lead Center for Focused Atmospheric Science Missions, conduct a world-class peer reviewed and selected atmospheric science program in support of national goals in preserving the environment and in fundamental science. Specific discipline areas of expertise are Earth radiation research, particularly the role of clouds in the Earth's energy budget; middle and upper atmospheric research; and troposhperic research. Perform innovative scientific research to advance the knowledge of atmospheric radiative, chemical, and dynamic processes for understanding global change; develop innovative passive and active sensor systems concepts for atmospheric science measurements. Conduct a

technology development program that develops advanced laser and LIDAR technologies for Earth science missions; advanced passive remote sensing technologies; develop advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of earth observation space instruments and systems. Conduct an Application and Educational Outreach program that utilizes scientific data for non-scientific applications and in support of science and math education. Serve as a Primary Data Analysis and Archival Center (DAAC) for Earth Radiation and Atmospheric Chemistry for the Earth Observing System.

SPACE SCIENCES -Support the solicitation and selection process of the Office of Space Science's (OSS) Discovery, Explorer and Solar Terrestrial Probes Programs; conduct reviews of candidate and selected missions and independent assessments of on-going space science missions to help ensure that OSS criteria for high quality science return within cost and schedule constrains are met. Conduct a technology development program that develops advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of space science instruments and systems. Langley is developing the SABER instrument which is on the TIMED mission to explore the mesosphere and lower thermosphere globally and achieve a major improvement in the understanding of the fundamental processes governing energetics, chemistry, dynamics and transport. Langley is also analyzing SAMPEX data to assess the relative importance of solar terrestrial coupling due to varying electron precipitation compared to that due to 11-year solar flux variations. Langley has provided and continues to provide analysis of spacecraft aerodynamics, aerothermodynamics and flight dynamics for spacecraft entering planetary atmospheres (including Earth) in support of both spacecraft design and flight operations. Langley is also
responsible for the design and development of the Earth Entry Vehicle for the Mars Sample Return Mission currently scheduled to launch in 2005.

LIFE AND MICROGRAVITY SCIENCES - Conduct space radiation exposure studies in support of current and future human space efforts for a more accurate assessment of astronaut radiation exposures and body shielding factors.

HUMAN EXPLORATION AND DEVELOPMENT OF SPACE - Support the Human Exploration and Development of Space through systems analyses of Space Station evolution and future human space exploration missions.

SYSTEMS ANALYSIS/INDEPENDENT PROGRAM EVALUATION AND ASSESSMENT - Serve as the Agency lead center for systems analysis and the conduct of independent evaluation, assessment, and cost estimation of Agency programs. Maintain, as a Center core competency, appropriate expertise and analysis tools to support the Agency's Strategic Enterprises in the definition and development of advanced systems concepts to achieve NASA's goals. Utilize core systems analysis capabilities (supplemented with expertise from other Centers as appropriate) to support the Office of the Administrator by conducting independent assessments of advanced concepts and proposed new systems to validate conceptual level designs prior to Agency commitment to major developmental funding. Provide Agencywide independent cost estimates and analysis for programs and projects. Support the Administrator's Program Management Council (PMC) in the organization, administration, and technical support of PMC review process.

CENTER MANAGEMENT AND OPERATIONS - Provide administrative and financial services in support of Center management and provide for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

LANGLEY RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**119**	**119**	**114**
Major Development Programs	15	15	3
Explorer Program	4	4	4
Mars Surveyor Program	35	35	37
Discovery Program	7	7	8
Operating Missions	5	5	0
Research and Technology	53	53	62
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**41**	**41**	**48**
International Space Station	30	30	36
Payload & ELV	11	11	12
EARTH SCIENCE	**292**	**292**	**295**
Earth Observing System Program	75	75	76
Earth Probes Program	13	13	15
Operating Missions	1	1	1
Research and Technology	203	203	203
AERO-SPACE TECHNOLOGY	**1,418**	**1,440**	**1,535**
Aero-Space Focused Programs	162	378	488
High Speed Research Program	105	0	0
Advanced Subsonics Tech Program	115	0	0
Aero-Space Base	958	984	968
Commercial Technology Program	42	42	43
Investment - AST	36	36	36
PROGRAM OPERATIONS	**458**	**490**	**395**
Corporate Programs	24	24	32
Center Operations	434	466	363
Total full-time equivalents	**2,328**	**2,382**	**2,387**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

GLENN RESEARCH CENTER at LEWIS FIELD

ROLES AND MISSIONS

LIFE AND MICROGRAVITY SCIENCES - The Glenn Research Center (GRC) provides leadership and management of the fluid physics, combustion science and acceleration measurement disciplines of NASA's Microgravity Science Program. Sponsors and conducts ground-based scientific studies that may lead to experiments in space. GRC has a substantial effort in the design, buildup, testing, integration and telescience operations of hardware for experiments to be launched aboard the Space Shuttle and the utilization of the Space Station for scientific missions.

SPACE STATION - GRC support to the space station program includes technical and management support in the areas of power and on-board propulsion components and system, engineering and analysis, technical expertise, and testing for components and systems. This includes use of facilities and testbeds and construction of flight hardware as required.

MISSION COMMUNICATIONS SERVICES - GRC develops and demonstrates communications and networks technologies in relevant environments to enhance the performance of existing mission services or enable new services. The Center identifies and infuses new capabilities at higher frequencies (Ka-band and above) into the next generation of spacecraft and communications satellites, to enable seamless interoperability between NASA assets and commercial space and ground networks. The Center also ensures timely and high quality availability of radio frequency spectrum to enable the realization of NASA goals.

AERONAUTICAL RESEARCH AND TECHNOLOGY - As the NASA Lead Center for Aeropropulsion, GRC conducts world-class research critical to the Agency Aero-Space Technology Enterprise goals of developing and transferring enabling technologies to U.S. industry and other government agencies. The Center's Aeropropulsion programs are essential to achieving National goals to promote economic growth and national security through safe, superior, and environmentally compatible U.S. civil and military aircraft propulsion systems. The Aeropropulsion Program spans subsonic, supersonic, hypersonic, general aviation, high performance aircraft, and access-to-space propulsion systems through innovative application of research in turbomachinery materials, structures, internal fluid mechanics, instrumentation and controls, interdisciplinary technologies, and aircraft icing. GRC has research expertise in world-class facilities critical to insuring U.S. leadership in aviation, FAA, EPA, and DOD in particular depend on NASA GRC research for advancements in emissions, noise, engine performance and new materials.

As the NASA Center of Excellence in Turbomachinery, GRC's expertise is critical to advancing the Agency's goals in the aeronautics and space programs. This enables GRC to be a cost effective resource across multiple Agency programs in the vital and strategic discipline area of turbomachinery. Turbomachinery based areas of expertise include air breathing

propulsion and power systems, primary and auxiliary propulsion and power systems, on-board propulsion systems, and rotating machinery for the pumping of fuels/propellants.

The Ultra Efficient Engine Technology Program is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical, reliable and environmentally compatible U.S. aircraft. The breakthrough technologies are focused on propulsion component and high temperature engine materials development and demonstrations enabling future commercial and military propulsion systems which are greatly simplified, achieve higher performance, and have potential for much reduced environmental impact with a broad range of aircraft application. Six investment areas form the basis for the technical approach: materials & structures, combustion, turbomachinery, intelligent propulsion system controls, integration & assessments, and integrated component technology.

CENTER MANAGEMENT AND OPERATIONS - Provides administrative and financial services in support of Center Management and provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
GLENN RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**211**	**185**	**178**
Research and Technology	211	185	178
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**373**	**449**	**421**
International Space Station	187	191	148
Space Operations (SOMO)	37	46	44
Life & Microgravity Sciences & Apps	149	212	229
AERO-SPACE TECHNOLOGY	**1,025**	**974**	**997**
Aero-Space Focused Programs	105	266	324
High Speed Research Program	140	0	0
Advanced Subsonics Tech Program	131	0	0
Aero-Space Base	595	665	631
Commercial Technology Program	32	20	20
Investment - AST	22	23	22
PROGRAM OPERATIONS	**382**	**375**	**376**
Corporate Programs	21	20	20
Center Operations	361	355	356
Total full-time equivalents	**1,991**	**1,983**	**1,972**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2001 ESTIMATES

NASA HEADQUARTERS

ROLES AND MISSIONS

NASA Corporate Headquarters

MISSION - The mission of Headquarters is to plan and provide executive direction for the implementation of U. S. space exploration, space science, aeronautics, and technology programs. This includes corporate policy development, program formulation, resource allocations, program performance assessment, long-term institutional investments, and external advocacy for all of NASA.

MAJOR CORPORATE ROLES - At NASA Headquarters, the broad framework for program formulation will be conducted through four Strategic Enterprises: Human Exploration and Development of Space, Earth Science, Aeronautics - Space Technology, and Space Science. Consistent with the NASA strategic plan, the Strategic Enterprises develop program goals and objectives to meet the needs of external customers within the policy priorities of the Administration and Congress.

Corporate level enabling processes and staff functions will provide cross-cutting interfaces required to support the Strategic Enterprises in legislative affairs, public affairs, budget and financial management, equal opportunity programs, human resources, education, legal affairs, procurement, international affairs, management systems and facilities, information systems and technology, small business, safety and mission quality, advisory committees, and policy and plans.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

NASA HEADQUARTERS

	FY 1999	FY 2000	FY 2001
PROGRAM OPERATIONS	**935**	**1,020**	**1,087**
Corporate Operations	935	1,020	1,087
Total full-time equivalents	**935**	**1,020**	**1,087**

DETAIL OF PERMANENT POSITIONS

	FY 1999	FY 2000	FY 2001
Executive level II	1	1	1
Executive level IV	2	2	2
Subtotal	**3**	**3**	**3**
ES-6	36	50	50
ES-5	70	109	109
ES-4	121	146	146
ES-3	52	70	70
ES-2	54	62	62
ES-1	66	68	68
Subtotal	**399**	**505**	**505**
CA	1	1	1
SL/ST	56	56	56
GS-15	2381	2392	2405
GS-14	3535	3567	3607
GS-13	5834	5866	5906
GS-12	1785	1817	1857
GS-11	1205	1205	1205
GS-10	244	244	244
GS-9	489	596	695
GS-8	261	261	261
GS-7	589	696	794
GS-6	490	490	490
GS-5	104	104	104
GS-4	20	20	20
GS-3	5	5	5
GS-2	2	2	2
Subtotal	**17,001**	**17,322**	**17,652**
Special ungraded positions established by NASA Administrator	26	26	26
Ungraded positions	309	309	309
Total permanent positions	**17,738**	**18,165**	**18,495**
Unfilled positions, EOY	0	0	0
Total, permanent employment, EOY	**17,738**	**18,165**	**18,495**

PERSONNEL SUMMARY

	FY 1999	FY 2000	FY 2001
Average GS/GM grade	12.53	12.48	12.43
Average ES salary	$121,218	$126,430	$131,942
Average GS/GM salary	$67,079	$70,299	$73,392
Average salary of special ungraded positions established by NASA Administrator	$88,071	$91,594	$95,624
Average salary of ungraded positions	$46,522	$48,383	$50,512

CENTER LOCATIONS AND CAPITAL INVESTMENT

JOHNSON SPACE CENTER - The Lyndon B. Johnson Space Center is located 20 miles southeast of Houston, Texas. NASA owns 1,581 acres of land at the Houston site and uses another 60,552 at the White Sands Test Facility, Las Cruces, New Mexico. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $2,339,529 as of September 30, 1999.

KENNEDY SPACE CENTER - The Kennedy Space Center is located 50 miles east of Orlando, Florida. NASA owns 82,943 acres and uses launch facilities at Cape Canaveral Air Station and Vandenberg Air Force Base. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,799,479 as of September 30, 1999.

MARSHALL SPACE FLIGHT CENTER - The Marshall Space Flight Center is located within the U.S. Army's Redstone Arsenal at Huntsville, Alabama. MSFC also manages operation at the Michoud Assembly 15 miles east of New Orleans, Louisiana and the Slidell Computer Complex in Slidell, Louisiana. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,935,733 as of September 30, 1999.

STENNIS SPACE CENTER - The Stennis Space Center is located approximately 50 miles northeast of New Orleans, Louisiana. NASA owns 20,663 acres and has easements covering an additional 118,284 acres. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $473,822 as of September 30, 1999.

GODDARD SPACE FLIGHT CENTER - The Goddard Space Flight Center is located 15 miles northeast of Washington, D.C. at Greenbelt, Maryland. NASA owns 1,121 acres at this location and an additional 6,176 acres at the Wallops Flight Facility in Wallops Island, Virginia. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $2,040,240 as of September 30, 1999.

AMES RESEARCH CENTER - The Ames Research Center is located south of San Francisco on Moffett Field, California. NASA owns 447.5 acres at the Moffett Field location. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $885,458 as of September 30, 1999.

DRYDEN FLIGHT RESEARCH CENTER - The Dryden Flight Research Center is 65 air miles northeast of Los Angeles. Dryden is located at the north end of Edwards Air Force Base on 838 acres of land under a permit from the Air Force. The total capital investment at Dryden, including fixed assets in progress and contractor-held facilities at various locations, as of September 30, 1999 was $391,893.

LANGLEY RESEARCH CENTER - The Langley Research Center is adjacent to Langley Air Force Base which is located between Williamsburg and Norfolk at Hampton, Virginia. NASA owns 788 acres and has access to 3,276 acres. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,002,192 as of September 30, 1999.

LEWIS RESEARCH CENTER The Lewis Research Center occupies two sites; the main site is in Cleveland, Ohio, adjacent to Cleveland-Hopkins Airport; the second site is the Plum Brook Station located south of Sandusky, Ohio, and 50 miles west of Cleveland. NASA owns 6,805 acres and leases an additional 14 acres at the Cleveland location. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $647,237 as September 30, 1999.

NASA HEADQUARTERS - NASA Headquarters is located at Two Independence Square, 300 E St. SW, Washington, D.C. and occupies other buildings in the District of Columbia, Maryland, and Virginia.

MISSION SUPPORT

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF MANAGEMENT SYSTEMS **CONSTRUCTION OF FACILITIES**

SUMMARY OF RESOURCES BY APPROPRIATION

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Human Space Flight Appropriation	17,800	13,200	16,300	MS 4-8
Science, Aeronautics and Technology Appropriation	19,500	24,200	37,500	MS 4-11
Mission Support Appropriations	168,500	181,900	245,900	MS 4-17
Total	205,800	219,300	299,700	

PROGRAM GOALS

The goal of the Construction of Facilities program is to ensure that the facilities critical to achieving NASA's space and aeronautics program are constructed and continue to function effectively, efficiently, and safely, and that NASA installations conform with requirements and initiatives for the protection of the environment and human health.

STRATEGY FOR ACHIEVING GOALS

NASA facilities are critical the shuttle, to sustaining payload and launch operations, and for providing critical national aeronautical and aerospace testing capabilities, which both support military and private industry users. NASA has conducted a thorough review of its facilities infrastructure finding that the that deteriorating plant condition warrants an increased repair and renovation rate to avoid safety hazards to personnel, facilities, and mission; and that some dilapidated facilities need to be replaced. Increased investment in facility revitalization is needed to maintain a facility infrastructure that is safe and capable of supporting NASA's missions. The Budget supports increased facilities funding to address these needs.

The Construction of Facilities (CoF) budget line item in the Mission Support appropriation provides for discrete projects required for components of the basic infrastructure and institutional facilities. Almost all of these projects are capital repair. The Mission Support appropriation also includes Minor Revitalization and Construction projects (projects greater than $500 thousand but not over $1.5 million), the design of facilities projects, and advanced planning related to future facilities needs. Funding for construction projects required to conduct specific Human Space Flight or Science, Aeronautics, and Technology programs or projects is included in the appropriate budget line item. Descriptions and cost estimates are shown as part of the Construction of Facilities program to provide a complete picture of NASA's budget requirement for facilities.

Within the Human Space Flight appropriations account, the Space Flight Operations (Space Shuttle) FY 2001 budget request includes Discrete projects to restore the wall and ceiling integrity of the Payload Changeout Room of Pad B at Kennedy Space Center and repair and upgrade Substations 20A/20B for the Vertical Assembly Building at the Michoud Assembly Facility. It also includes minor projects less than $1,500,000 required to support specific programs. The Science, Aeronautics, and Technology appropriations account includes budget requests for Discrete projects in Aero-Space Technology, to replace the fan blades in the National Full-scale Aerodynamic Complex at Ames Research Center and to construct a Rocket-Based Combined Cycle Test Facility at the Stennis Space Center; in Space Sciences, to construct a Laboratory for In-Situ Microbiology at Jet Propulsion Laboratory; and in Life and Microgravity Sciences and Applications, to continue construction of the Booster Application Facility at Brookhaven National Laboratory.

Mission Support funding is requested in FY 2001 for discrete projects to repair and modernize deteriorating and obsolete building and utility systems that have reached or exceeded their normal design life, are no longer operating effectively or efficiently, and cannot be economically maintained. These systems include mechanical, structural, cooling, steam, electrical distribution, sewer, and storm drainage at Ames Research Center, Glenn Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, Michoud Assembly Facility, and Wallops Flight Facility. Also included is a project to upgrade the 34-meter beam wave-guide antenna subnet of the Deep Space Network for Ka-band operation and three projects to replace old dilapidated trailers and boxcars with new facilities at Kennedy Space Center. Should residual resources become available from these projects, they will be used for urgently needed facility revitalization requirements. Congress will be notified before work is initiated for any such project that exceeds $1,500,000.

The Minor Revitalization and Construction program included in this request continues the vital rehabilitation, modification, and repair of facilities to renew and help preserve and enhance the capabilities and usefulness of existing facilities and ensure the safe, economical, and efficient use of the NASA physical plant. The Minor Revitalization and Construction program also replaces substandard facilities in cases where it is more economical to demolish and rebuild than it is to restore. In selected cases, additional square footage may be built when there are compelling reasons to support new or specialized technical and/or institutional requirements of a nature that cannot be provided by using existing facilities.

Funds requested for Facility Planning and Design cover advance planning and design requirements for potential future projects, preparation of facility project design drawings and bid specifications, master planning, facilities studies, and engineering reports and studies. Also included are critical functional leadership activities directed at increasing the rate of return of constrained Agency resources while keeping the facility infrastructure safe, reliable, and available.

The Mission Support Appropriation also includes the Environmental Compliance and Restoration (ECR) Program which is critical to ensuring that statutory and regulatory environmental requirements and standards are met. NASA's environmental strategy demonstrates our commitment to protect the environment and provides for the protection and safety of human health. This commitment is achieved by focusing and directing our leadership and efforts into the principal areas of environmental compliance, remediation, restoration and conservation, and prevention. The requested funds cover environmental activities required for compliance with environmental statutory and regulatory requirements and standards, orders, regulatory and cooperative agreements and support of environmental program initiatives.

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
HUMAN SPACE FLIGHT	17,800	13,200	16,300	
INTERNATIONAL SPACE STATION	1,200	---	---	
Modifications for Electrical Power Upgrades, Building 30S (JSC)	1,200	---	---	
SPACE FLIGHT OPERATIONS (SPACE SHUTTLE)	13,500	11,000	15,500	
Repair Payload Changeout Room, Pad B (KSC)	---	---	2,300	MS 4-9
Repair and Upgrade Substations 20A/20B (MAF)	---	---	1,800	MS 4-10
Refurbish Elevator Controls, Vehicle Assembly Building (KSC)	---	2,300	---	
Restore Pad Surfaces and Slopes, Pad B (KSC)	---	1,800	---	
Rehabilitate 480V Electrical Distribution System, ET Manufacturing Bldg. (MAF)	2,000	1,800	---	
Construct Safe Haven, LC 39 (KSC)	5,900	---	---	
Refurbish Pad A Fixed Support Structure Elevator System (KSC)	2,300	---	---	
Refurbish Pad A Flame Deflector and Trench (KSC)	1,500	---	---	
Repairs to Cleaning Cell E, Vertical Assembly Building (MAF)	1,800	---	---	
Minor Revitalization and Construction of Facilities at Various Locations, Not in excess of $1,500,000 per project	---	2,400	8,600	MS 4-38
Facility Planning and Design	---	2,700	2,800	
PAYLOAD AND ELV SUPPORT	3,100	2,200	800	
Rehabilitate and Modify Launch Vehicle Data Center, Hangar AE, Cape Canaveral Air Station (CCAS) (KSC)	700	---	---	
Replace Backup Power Supply System, VAFB, SLC-2 (KSC)	900	---	---	
Rehabilitate E&O Building, CCAS (KSC)	1,500	---	---	
Minor Revitalization and Construction of Facilities at Various Locations, Not in excess of $1,500,000 per project	---	2,200	800	MS 4-38

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
SCIENCE, AERONAUTICS, AND TECHNOLOGY	19,500	24,200	37,500	
SPACE SCIENCE	12,000	2,500	13,000	
Construct Laboratory for In-Situ Microbiology (JPL)	---	---	13,000	MS 4-12
Construct Optical Interferometry Development Laboratory (JPL)	2,500	2,500	---	
Modification of Stratospheric Observatory for Infrared Astronomy (SOFIA) Ground Support Facility (ARC)	7,000	---	---	
Restore Meteorological Development Laboratory (GSFC)	2,500	---	---	
LIFE AND MICROGRAVITY SCIENCE AND APPLICATIONS	3,500	9,000	8,500	
Construct Booster Applications Facility, Brookhaven National Laboratory, Phase 4	3,500	9,000	8,500	MS 4-13
EARTH SCIENCE	1,500	1,000	---	
Restore Meteorological Development Laboratory (GSFC)	1,500	1,000	---	
AERO-SPACE TECHNOLOGY	2,500	11,700	16,000	
Replace Fan Blades, National Full-scale Aerodynamic Complex, Phase 3 (ARC)	2,000	3,400	6,000	MS 4-15
Construct Rocket-Based Combined Cycle (RBCC) Test Facility (SSC)	---	1,000	10,000	MS 4-16
Replace Main Drive for 14x22-Foot Subsonic Tunnel (LaRC)	500	7,300	---	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
MISSION SUPPORT CONSTRUCTION OF FACILITIES (COF)		(Thousands of Dollars)		
Restore Electrical Distribution System (ARC)	2,200	2,700	9,000	MS 4-18
Provide 34.5kV Alternate Feed to Substation G (GRC)	---	---	4,500	MS 4-19
Rehabilitate Distributed Control System (GRC)	---	---	3,000	MS 4-20
Repair Sanitary Sewer System (GRC)	---	---	4,400	MS 4-21
Repair Site Steam Distribution System (GSFC)	2,000	2,900	4,000	MS 4-22
Restore Chilled Water Distribution System (GSFC)	---	3,900	5,000	MS 4-23
Replace Chillers, Space Flight Operations Facility (JPL)	---	---	1,800	MS 4-24
Upgrade 34-Meter Beam Waveguide Antenna Subnet for KA-Band, Network (JPL)	---	---	1,900	MS 4-25
Rehabilitate Electrical Distribution System, 200 Area, WSTF (JSC)	---	---	2,500	MS 4-26
Construct Operations Support Building, Hypergol Maintenance Facility (KSC)	---	---	3,300	MS 4-27
Construct Operations Support Building, Pad B (KSC)	---	---	4,000	MS 4-28
Construct Operations Support Building II, LC-39 Area (KSC)	---	---	13,000	MS 4-29
Repairs to Primary Electrical Power System, (KSC)	---	---	3,500	MS 4-31
Repairs to Electrical Systems, East and West Areas (LaRC)	---	---	9,000	MS 4-32
Repair and Modernize Fluid Dynamics Vacuum Pump Facility (MSFC)	---	---	2,600	MS 4-33
Replace Roof, Building 4705 (MSFC)	---	---	2,400	MS 4-34
Replace Mechanical Equipment and Roof, Building 350 (MAF)	---	---	5,800	MS 4-35
Repair Storm Drainage System (WFF)	---	---	2,700	MS 4-36
Rehabilitate Hangar, Building 4802 (DFRC)	---	2,900	---	
Rehabilitate High Voltage System (GRC)	8,300	7,600	---	
Upgrade 70M Antenna Servo Drive, 70M Antenna Subnet (JPL)	---	3,400	---	
Rehabilitate Utility Tunnel Structure and Systems (JSC)	---	5,600	---	
Connect KSC to CCAS Wastewater Treatment Plant (KSC)	---	2,500	---	
Rehabilitate High Pressure Storage System, LC-39 (KSC)	---	3,400	---	
Replace High Voltage Load Break Switches (KSC)	---	1,400	---	
Repair Roofs, Vehicle Component Supply Buildings (MAF)	---	2,000	---	
Replace Air Storage Field, 8-FT High Temperature Tunnel (LaRC)	---	10,000	---	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
MISSION SUPPORT COF (Continued)				
Modernization of Process Cooling System, Numerical Aerodynamic Simulation Facility (ARC)	2,700	---	---	
Contractor Claim on Project to Construct Integrated Test Facility (DFRC)	2,000	---	---	
Restoration of Space/Terrestrial Application Facility (GSFC)	5,000	---	---	
Construction of In-Situ Instruments Laboratory (JPL)	5,000	---	---	
Replacement of Central Plant Chilled Water Equipment (JSC)	5,200	---	---	
Upgrade of Utility Annex Chilled Water Plant (KSC)	1,900	---	---	
Rehabilitation of Instrument Research Laboratory (LARC)	3,100	---	---	
Modification of Chilled Water System (MSFC)	7,200	---	---	
Construction of Addition to Administration Building (SSC)	1,500	---	---	
Minor Revitalization and Construction of Facilities at Various Locations, Not in excess of $1,500,000 per project	68,400	79,300	106,800	MS 4-38
Facility Planning and Design	14,000	14,200	15,700	MS 4-43
Environmental Compliance and Restoration	40,000	40,100	41,000	MS 4-46
Total - Mission Support	168,500	181,900	245,900	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY

HUMAN SPACE FLIGHT

	Amount (Thousands)	Page Number
Space Flight Operations (Space Shuttle):		
Repair Payload Changeout Room, Pad B (KSC)	2,300	MS 4-9
Repair and Upgrade Substations 20A/20B (MAF)	1,800	MS 4-10
Minor Revitalization of Facilities at Various Locations, Not in excess of $1,500,000 per project	8,600	MS 4-38
Facility Planning and Design	2,800	
Payload and ELV Support:		
Minor Revitalization of Facilities at Various Locations, Not in excess of $1,500,000 per project	800	MS 4-38
Total Human Space Flight	16,300	

PROJECT TITLE: Repair Payload Changeout Room, Pad B
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Kennedy Space Center
LOCATION: Brevard County, Merritt Island, FL

FY 01 COST ESTIMATE (Thousands of Dollars):	2,300
Project Element:	
Civil and Structural	1,900
Mechanical	200
Electrical	200

PRIOR YEARS FUNDING:	107,684
Construction	---
Facility Planning and Design	184
Capitalized Investment	107,500

PROJECT DESCRIPTION:
This project replaces damaged Payload Changeout Room (PCR) wall panels, replaces or eliminates various leaking access doors, replaces the ceiling grid assembly, and illuminates the access area within the PCR plenum. The high efficiency particulate air (HEPA) filter housing will be reconfigured to allow safer accessibility.

PROJECT JUSTIFICATION:
The Launch Complex 39 Pad B PCR was built in circa 1976 to provide a pressurized, contaminant-free environment for pre-flight servicing of Space Shuttle hardware. However, the PCR can no longer be pressurized because of structural and mechanical defects in exterior walls and access doors caused by severe weather-related damage and prolonged deterioration. As a result, contamination levels within the PCR have increased alarmingly. Friable insulation associated with mechanical components also contributes to the contamination. Current conditions will soon cause the payload-processing environment to exceed acceptable limits for contamination and pressurization capability and therefore become a launch constraint. This project replaces damaged structures that allow contaminants to enter the PCR's controlled space. Project completion is essential to avoid costly launch delays that would occur if the PCR lost its capability to maintain a controlled environment.

This project was originally in the FY 2000 budget but was deferred to accommodate an urgent safety project when the launch window required to accomplish the project moved due to changes in the Shuttle launch manifest. The urgent safety project substituted in its place repairs the elevator controls in the Vehicle Assembly Building.

IMPACT OF DELAY:
Repairs to the PCR can no longer be operationally deferred. Failure to repair the PCR structure and supporting mechanical systems would risk exposure of Space Shuttle hardware to contamination levels that exceed acceptable limits. This would hinder Space Shuttle launch preparation and cause costly launch delays. Operations and maintenance costs associated with keeping the deteriorated structure and mechanical components would continue to increase.

PROJECT TITLE: Repair and Upgrade Substations 20A/20B
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Michoud Assembly Facility
LOCATION: New Orleans, Orleans Parish, LA

FY 01 COST ESTIMATE (Thousands of Dollars):	1,800
Project Element:	
Site Preparation and Demolition	265
Switchgear and Breakers	525
Motor Control Centers, Switchboards, and FDR Sections	400
Enclosure with Bus Duct	175
Wires and Cable Terminations	250
Miscellaneous Fittings and Components	185

PRIOR YEARS FUNDING:	312
Construction	---
Facility Planning and Design	140
Capitalized Investment	172

PROJECT DESCRIPTION:
This project repairs and upgrades the main electrical distribution system servicing the Vertical Assembly Building (110) and the Mix Room Building (130). The project includes replacement of switchgear, 480-volt feeders, motor control centers, 480/277-volt power panels, switchboards, bus duct, transfer switches, 13.8-kilovolt switches, and other related electrical components.

PROJECT JUSTIFICATION:
The transformers in Substation 20A/20B were replaced in 1986, but all remaining components have not been replaced since the substation was built in 1963. Substation components exceed design life expectancy. Breakers and other spare parts are difficult and costly to obtain in a timely matter because they are no longer in production and require custom fabrication. The substation has experienced widespread deterioration of the feeder insulation, 480-volt panels, and motor control centers. Non-grounded bus duct is utilized throughout the system posing a safety hazard.

Substation 20A/20B provides electrical power to vital production activities in Buildings 110 and 130. Building 110 houses External Tank production cells for the manufacturing of the LH2 and LO2 tanks; internal and external cleaning; spray-on foam insulation (SOFI) application and curing; LH2 hydrostatic testing; and vehicle staking and mating. Building 130 houses the mix room for the formulation and mixing of super light ablator (SLA) and the pretreatment of cork and micro-balloons. Reliable power for Buildings 110 and 130 is essential to avoid costly disruptions to the External Tank (ET) production schedule.

IMPACT OF DELAY:
Continued operation of unreliable and unsafe electrical equipment at Substation 20A/20B would increase risk of injury to personnel, damage to property, and disruption of ET manufacturing activities. Operations and maintenance costs would stay excessively high. Personnel maintaining antiquated and unsafe equipment would continue to do so at increasing exposure to possible severe injury. Unexpected power disruptions would impact the ET production schedule.

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY

SCIENCE, AERONAUTICS, AND TECHNOLOGY

	Amount (Thousands)	Page Number
Space Science:		
Construct Laboratory for In-Situ Microbiology (JPL)	13,000	MS 4-12
Life and Microgravity Science and Applications:		
Construct Booster Applications Facility, Brookhaven National Laboratory, Phase 4	8,500	MS 4-13
Aero-Space Technology:		
Replace Fan Blades, National Full-scale Aerodynamic Complex, Phase 3 (ARC)	6,000	MS 4-15
Construct Rocket-Based Combined Cycle (RBCC) Test Facility (SSC)	10,000	MS 4-16
Total Science, Aeronautics, and Technology	37,500	

PROJECT TITLE: Construct Laboratory for In-Situ Microbiology
COGNIZANT OFFICE: Office of Space Science

INSTALLATION: Jet Propulsion Laboratory
LOCATION: La Canada-Flintridge, Los Angeles County, CA

FY 01 COST ESTIMATE (Thousands of Dollars)	13,000
Project Elements:	
Sitework	650
Architectural/Structural	4,550
Mechanical	3,900
Electrical	3,900

PRIOR YEARS FUNDING:	1,040
Construction	---
Facility Planning and Design	1,040
Capitalized Investment	---

PROJECT DESCRIPTION:
The Laboratory for In-Situ Microbiology (LIMB) will be a first of its kind facility needed to support outbound spacecraft performing interplanetary sampling. This project constructs a new three-story 3200 square meter laboratory. It will have a large Class 10,000 cleanroom with high ceiling to accommodate clean tents, associated garment areas, air locks and air showers for equipment and personnel access; a Class-1000 cleanroom with a low-vibration environment for prototype development; chambers with thermal-vacuum capabilities; a surface exploration laboratory for development and demonstration of telerobotic systems; and offices for 50 engineers and scientists using these facilities. The structure will be seismically reinforced steel on a concrete foundation and have solar-resistant glass. The LIMB will be sited next to the In-Situ Instruments Laboratory and will use Building 303 utilities to the extent practicable. Special consideration will be given to achieving low vibration levels, and providing an air-handling system with sufficient capacity and filtration for backward and forward biological decontamination. Separate air handling systems will be needed for the biological and biochemical areas, the surface exploration area, and the electronics prototype area.

PROJECT JUSTIFICATION:
The LIMB will allow for the development of interplanetary systems that will search for evidence of past or present life forms from a spacecraft free of contamination from Earth organisms or residue. The proposed, special facility will allow detection and removal of biological contaminants in clean areas developed around new methods and procedures for biological decontamination during hardware fabrication and assembly. These requirements are unprecedented in the history of robotic space missions. The facilities and equipment for meeting them are not available anywhere in the world.

The LIMB will provide cleaning and sterilization at various stages of electronic materials assembly to meet the stringent biological decontamination requirements of flight hardware that will visit other planetary bodies. The LIMB will provide sufficient flexibility and adequate capacity to permit variances in the sequence and procedures to accommodate the new technology needed in the decontamination process for assembly of the electronic materials. For purposes of clarity, this facility will not support research activities on returned samples. This new building represents the program plan at the time of the budget submission to Congress. There may be some adjustment needed to the project based on results of the planned reevaluation of the Mars program.

IMPACT OF DELAY:
NASA will be unable to meet program and project commitments related to In-Situ Microbiology.

PROJECT TITLE: Construct Booster Applications Facility, Phase 4
COGNIZANT OFFICE: Office of Life and Microgravity Sciences and Applications

INSTALLATION: Brookhaven National Laboratory
LOCATION: Long Island, NY

FY 01 COST ESTIMATE (Thousands of Dollars):	8,500
Project Element:	
Conventional Construction	1,200
Booster Modifications	1,300
Beam Transport System	2,400
Controls and Personnel Safety System	1,000
Experimental Area Outfitting	1,400
Installation and Services	700
Project Services	500

PRIOR YEARS FUNDING:	12,800
Construction	12,800
Facility Planning and Design	---
Capitalized Investment	---

PROJECT DESCRIPTION:
This project constructs a Booster Applications Facility (BAF) adjacent to the existing Brookhaven National Laboratory (BNL) Alternating Gradient Synchrotron (AGS) Booster. Conventional construction includes site clearing and preparation; new roads and parking areas; booster wall penetration; tunnel construction with access/egress corridors at both ends of the tunnel; and construction of two pre-engineered metal buildings, one for protecting power supplies and switchgear, and the other to provide laboratory workspace. The project modifies the AGS Booster to accommodate installation of hardware required to perform slow extraction. Booster modifications include relocation of the beam dump and a wall current monitor; installation of new septum magnets; provision of new power supplies; rewiring for higher currents; and reconfiguration of exiting vacuum chambers. The project constructs a 63-meter Beam Transport System (BTS) in the new tunnel capable of providing a 20-degree bend (to eliminate direct line-of-sight) between the booster ring and the target area, and capable of distributing the beam over a 15-centimeter x 15-centimeter target area. The BTS consists of a 10-centimeter diameter vacuum pipe with a thin window in front of the target and a fast-closing valve to protect the booster vacuum from a window break; magnetic elements to transport and shape the beam on target; a cooling system using low conductivity water; and cable trays and cabling for direct current (DC) power and controls. The project includes all distributed systems, central services, and process controls required for operation of the BAF, including a relay-based personnel access control system that permits entrance to radiation areas only when safe to do so. The project upgrades one of the two existing BNL Tandem accelerators to 16 megavolts and modifies it to enable concurrent use by AGS and BAF. The project provides for outfitting of the experimental areas for research in biological systems, including dosimeters, computer systems, and other electronic equipment. Project provides for all supporting infrastructure and utilities. This is the fourth increment of this $33.1 million project. Future construction funds in the amount of $11.8 million are budgeted in FY02-03 to complete the project.

PROJECT JUSTIFICATION:
The BAF will provide a ground-based facility in which to conduct important research aimed at understanding and assessing health risks and developing effective countermeasures against galactic cosmic radiation. Such a capability does not currently exist. The BAF will provide the capability to simulate all major ion components and energies of the galactic cosmic rays and solar proton events. Once the BAF becomes operational, BNL will provide NASA access to more than 2,000 beam-hours-per-year in order to meet all of the goals of NASA's Strategic Radiation Health Plan.

The BAF will benefit the International Space Station (ISS) by providing a ground-based facility for meeting operational, scientific, and technology goals in radiation protection. The BAF will provide a capability for accurate calibration of radiation detectors used to monitor crewmember exposures on ISS and verify doses as regulated by OSHA. It will also provide a facility for developing shielding augmentation for ISS, which would increase astronaut safety and extend crew stays. The BAF will enable critical research and measurements for assessing health risks from heavy-ions that comprise up to 50 percent of the biological dose on ISS. Acquiring this scientific knowledge will allow NASA to maximize crew stay times and reduce costs from excessive crew changes.

The National Research Council and the National Council of Radiation Protections and Measurements in independent reviews have informed NASA that the scientific basis to estimate risk from galactic cosmic radiation during long-term space flight does not exist. The BAF will benefit long-duration missions by providing a unique ground-based facility in which to conduct critical research to obtain knowledge of potential health effects and for the development of ground analogs, biological countermeasures, and radiation shielding strategies.

IMPACT OF DELAY:
Delaying this project would greatly impact NASA's ability to pursue vital research on space radiation effects required to enable development of maximum-exposure guidelines and of radiation countermeasures such as shielding. NASA's ability to safely carry out extended crew stays at the ISS and other potential future long-duration space flightswould be severely curtailed. Delay of this project would also delay our ability to calibrate radiation detectors without which NASA cannot accurately monitor ISS crewmembers' exposure to radiation. These impacts will translate into increased ISS operations cost due to more frequent crew changes, and increased risk to astronauts due to limited knowledge of space radiation effects.

PROJECT TITLE: Replace Fan Blades, National Full-Scale Aerodynamic Complex, Ph 3 INSTALLATION: Ames Research Center
COGNIZANT OFFICE: Office of Aero-Space Technology LOCATION: Santa Clara County, CA

FY 01 COST ESTIMATE (Thousands of Dollars)	6,000	PRIOR YEARS FUNDING:	6,210
Project Elements:		Construction	5,400
Manufacture New Blades	6,000	Facility Planning and Design	810
		Capitalized Investment	---

PROJECT DESCRIPTION:
The scope of this project is to design, manufacture, and install new composite fan blades in the National Full-Scale Aerodynamic Complex (NFAC) at Ames Research Center. Composites are the most viable materials for replacing the temporary repaired blades. Composite blades will be substantially lighter than the current wood blades and have better damage tolerance characteristics, resulting in superior performance and increased durability. Future funding in the amount of $4 million is budgeted to complete this project. When combined with FY 99/00 funding of $5.4 million the total cost of this project is $15.4 million.

PROJECT JUSTIFICATION:
The NFAC is a vital National facility that supports aerodynamic and aeroacoustic testing for research and development of fixed and rotary winged aircraft. The NFAC is comprised of two large-scale wind tunnels that share a common fan drive system. The fan blades have developed significant cracking. An interim repair has been implemented until new blades can be procured. The NFAC fan drive system was modified when the 80 X 120 wind tunnel was added in the late 1970's. Each of six fans was upgraded and the number of blades was increased to 15 per fan. The new blades were made from a laminated wood product called "Hydulignum". This material was used as the main structural component of the blades, while the leading and trailing edges and the outer tip region were made of spruce. The attachment of the blades to the fan drive was accomplished via a metal cuff that was threaded onto the root end of the blade. These blades continued in operation until 1996 when numerous cracks were discovered in the "hydulignum" emanating from the root attachment area. An investigation revealed a higher dynamic loading on the blades than considered in the design. This caused the blades to vibrate at a rate 4 times greater than expected. The blades effectively reached their 40-year "fatigue life" after only 10 years of actual operation. Temporary repairs, consisting of injecting the cracks with high strength epoxy adhesive and wrapping the lower portion of the blade and steel cuff with a carbon composite material, are complete. Based on fatigue tests, the temporary repairs will last for a maximum of 5-6 years. Replacement of the fan blades must be accomplished to avoid potential shutdown of the facility.

IMPACT OF DELAY:
Failure to approve this project will result in increased cost, disruption, and delay to commercial and military aviation programs. If not available in a timely manner, the new blades would not be installed before the repaired blades reach the end of their safe operating lives, thereby causing disruption of NFAC operations.

PROJECT TITLE: Rocket-Based Combined Cycle (RBCC) Test Facility
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Stennis Space Center
LOCATION: Bay St. Louis, MS

FY 01 COST ESTIMATE (Thousands of Dollars)	10,000

PRIOR YEARS FUNDING:	1,000
Construction	---
Facility Planning and Design	1,000
Capitalized Investment	---

PROJECT DESCRIPTION:
Trade studies were initiated in FY 2000 to define the cost and capability of an advanced Rocket-Based Combined Cycle (RBCC) Test Facility necessary to address Spaceliner 100 requirements generated by the Space Transfer and Launch Technology Program. Contractors will be selected to initiate detail designs and specifications of the major systems such as propellant and pressurization systems, air storage and delivery, thrust measurement, instrumentation and control systems.

The advanced RBCC Test Facility activities will be focused on the preliminary design review (PDR). This will be used to finalize the requirements, design approach and major procurements. All civil and site work is to be completed in FY 2001 and activities will be initiated on ancillary systems.

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY OF RESOURCES REQUIREMENTS

MISSION SUPPORT APPROPRIATIONS	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
Discrete Projects	46,100	48,300	82,400	MS 4-18
Minor Revitalization and Construction	68,400	79,300	106,800	MS 4-38
Facility Planning and Design	14,000	14,200	15,700	MS 4-44
Environmental Compliance and Restoration	40,000	40,100	41,000	MS 4-47
TOTAL	168,500	181,900	245,900	
Distribution of Program Amount by Installation				
Johnson Space Center	21,819	14,050	31,820	
Kennedy Space Center	20,875	31,500	49,260	
Marshall Space Flight Center	30,136	25,365	33,010	
Stennis Space Center	12,600	10,925	16,760	
Ames Research Center	14,875	12,655	21,605	
Dryden Flight Research Center	4,357	6,582	5,910	
Glenn Research Center	17,319	19,303	25,030	
Langley Research Center	9,307	20,270	17,900	
Goddard Space Flight Center	18,513	21,320	22,360	
Jet Propulsion Laboratory	15,810	17,138	19,120	
Headquarters	2,889	2,792	3,125	
TOTAL	168,500	181,900	245,900	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2001 ESTIMATES

SUMMARY

MISSION SUPPORT

	Amount (Thousands)	Page Number
Mission Support Discrete Projects:		
Restore Electrical Distribution System, Phase 3 (ARC)	9,000	MS 4-19
Provide 34.5kV Alternate Feed to Substation G (GRC)	4,500	MS 4-20
Rehabilitate Distributed Control System (GRC)	3,000	MS 4-21
Repair Sanitary Sewer System, Phase 3 (GRC)	4,400	MS 4-22
Repair Site Steam Distribution System, Phase 3 (GSFC)	4,000	MS 4-23
Restore Chilled Water Distribution System, Phase 5 (GSFC)	5,000	MS 4-24
Replace Chillers, Space Flight Operations Facility (JPL)	1,800	MS 4-25
Upgrade 34-Meter Beam Waveguide Antenna Subnet for KA-Band, Network (JPL)	1,900	MS 4-26
Rehabilitate Electrical Distribution System, 200 Area, WSTF (JSC)	2,500	MS 4-27
Construct Operations Support Building, Hypergol Maintenance Facility (KSC)	3,300	MS 4-28
Construct Operations Support Building, Pad B (KSC)	4,000	MS 4-29
Construct Operations Support Building II, LC-39 Area, Phase 1(KSC)	13,000	MS 4-30
Repairs to Primary Electrical Power System, (KSC)	3,500	MS 4-32
Repairs to Electrical Systems, East and West Areas (LaRC)	9,000	MS 4-33
Repair and Modernize Fluid Dynamics Vacuum Pump Facility (MSFC)	2,600	MS 4-34
Replace Roof, Building 4705 (MSFC)	2,400	MS 4-35
Replace Mechanical Equipment and Roof, Building 350 (MAF)	5,800	MS 4-36
Repair Storm Drainage System, Phase 1 (WFF)	2,700	MS 4-37
Total Discrete Projects	82,400	

PROJECT TITLE: Restore Electrical Distribution System, Phase 3
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Ames Research Center
LOCATION: Moffett Field, Santa Clara County, CA

FY 01 COST ESTIMATE (Thousands of Dollars)	9,000
Project Elements:	
Substation Repairs/Upgrades	1,400
Replace Relays	750
Replace Arc Jet Supply Voltage Sys	400
Expand APMS	3,500
Replace/install Switchgear	2,950

PRIOR YEARS FUNDING:	15,457
Construction	4,900
Facility Planning and Design	761
Capitalized Investment	9,796

PROJECT DESCRIPTION:
This project will modernize and repair the Center's primary electrical distribution system as part of a phased program to improve reliability. The full cost of the all phases will be approximately $50M. Due to increasing safety concerns, this phase replaces approximately fifteen (15) 115kv air disconnect switches, eighty-four (84) electro-mechanical relays with microprocessor relays, and forty (40) underground oil switches with above-ground gas circuit breakers. The scope includes installing two (2) new 115kv gas circuit breakers on incoming transmission lines in the main substation; installing a graphic panel in the control room of Substations N225 and N225B to indicate new gas circuit breakers; replacing existing 2,400-volt Arc Jet supply voltage auxiliary system with new 4,160-volt supply; and expanding the Ames Power Monitoring System (APMS) Center-wide to include approximately eighty-four (84) buildings, ten (10) wind tunnels, and five (5) main electrical substations.

PROJECT JUSTIFICATION:
The existing Center-wide electrical system at Ames is worn out, unreliable, and in some cases unsafe. As a result, Ames has experienced increasing instances of power interruptions that have adversely impacted critical research. Much of the electrical equipment, such as the 115,000-volt oil circuit breakers, air operated switches, and metering systems, was installed during or shortly after 1945. The Center frequently must hand fabricate replacement parts because spares are no longer available for the majority of electrical equipment in this system. Many of the oldest electro-mechanical relays at the Center can no longer be calibrated because of worn mechanical components, and replacement parts are no longer available. New relays can be purchased for less cost than repairing the old relays. The existing APMS is over 30 years old. The data transmitted is not dependable and the accuracy of measurement is unpredictable. The existing system is not reliable for monitoring of electrical systems. Existing underground oil switches are unsafe when energized, and many are frequently flooded due to the high water table and infiltration of surface water. The existing Arc Jet 2,400-volt auxiliary supply has deteriorated and is unreliable. Safe operation is dependent on this supply, which provides power to the de-ionized cooling water system.

IMPACT OF DELAY:
Risk of injury to personnel maintaining hazardous underground oil switches would continue. In addition, power outages caused by electrical equipment failure will continue to not only adversely interrupt mission-critical research across the Center, but also prevent the Center from operating in an efficient, cost effective manner.

PROJECT TITLE: Provide 34.5 kV Alternate Feed To Substation G
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Glenn Research Center
LOCATION: Cleveland, OH

FY 01 COST ESTIMATE (Thousands of Dollars)	4,500
Project Elements:	
Duct bank to Substation G	3,900
34.5 KV Cable, Terminations, Splices	500
Breaker, Disconnects, Controls, Relaying	100

PRIOR YEARS FUNDING:	450
Construction	---
Facility Planning and Design	450
Capitalized Investment	---

PROJECT DESCRIPTION:
This project installs a permanent 25-megawatt alternate power supply to meet the base institutional needs of the Glenn Research Center (GRC) at Lewis Field in case of an extended interruption to the existing main supply of power from the Cleveland Electric Illuminating CO. (CEI). The project consists of installation of a permanent 25-megawatt alternate power supply to Substation G at GRC from an alternate Cleveland Electric Illuminating Co. (CEI) power source. The work includes a CEI designed and constructed underground duct bank with 34.5 KV cables from CEI's 34.5 KV tie point near Brookpark Rd. to Substation G. Work also includes installation of tie breaker with foundation at Substation G disconnects, relays, terminations, splices, controls, and protective relaying as required.

PROJECT JUSTIFICATION:
Glenn Research Center receives their full, 375-Megawatt electrical energy requirement from only one supply source; a single point of failure situation unique in NASA. The existing aerial, high-tension lines lay just below the aircraft approach and takeoff envelopes for the proposed new runways planned as part of the pending expansion of Cleveland airport. The potential of an extended interruption to the existing power supply presently exists and will statistically increase with the airport expansion adjacent to GRC. This power consists of both the approximate 25 megawatts needed to keep all institutional aspects (which include lighting, environmental systems, computing systems, and life safety systems) of over 100 facilities operational and the approximate 350 megawatts required for research operations at the facilities. This project only insures that base institutional power needs will be met if the main power supply is interrupted, not the much larger demand for research operations.

IMPACT OF DELAY:
Higher volumes of air traffic expected from the addition of a new airport runway and extension of other runways increases the probability of a loss of total supply power to GRC due to an aircraft accident. A minimum of three weeks would be required to restore some temporary power to GRC. The start of any activity for restoration of power would be impacted by such things as a FAA investigation and the clearing of debris from the site.

PROJECT TITLE: Rehabilitate Distributed Control System
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Glenn Research Center
LOCATION: Cleveland, OH

FY 01 COST ESTIMATE (Thousands of Dollars)	3,000
Project Elements:	
Master Stations (Hardware/Software)	1,500
Field Processors	1,000
Local Control/Instrumentation	500

PRIOR YEARS FUNDING:	1,897
Construction	---
Facility Planning and Design	300
Capitalized Investment	1,597

PROJECT DESCRIPTION:
The Distributed Control System Monitoring Station is located in the Central Control Building (143) and provides centralized equipment operator stations, air distribution scheduling, electrical power distribution, data collection, and operational reporting that must be modernized. This project rehabilitates aging signal conditioning and uninterruptible power supply equipment, modifies central process systems control to provide full automation, installs improved remote machinery monitoring, and upgrades distributed control system hardware and software.

PROJECT JUSTIFICATION:
The Distributed Control System is critical for providing safe centralized operational support of process systems for research programs associated with the development of advanced aeropropulsion systems. The industry standard for useful life of computer hardware and software is nominally three years although NASA routinely exceeds this standard. However, the Distributed Control System hardware and software is over ten years old. Equipment is obsolete and spare parts no longer available. This project is required to eliminate remaining manual control and monitoring. This project enhances machinery monitoring to improve reliability, reduces unforeseen maintenance, and minimizes the need to expose floor personnel to hazards and noise.

IMPACT OF DELAY:
The delay of this project significantly increases the risk of unscheduled and lengthy shutdowns of one or more major aeronautical research facilities.

PROJECT TITLE: Repair Sanitary Sewer System, Phase 3
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Glenn Research Center
LOCATION: Cleveland, OH

FY 01 COST ESTIMATE (Thousands of Dollars)	4,400
Project Elements:	
Sanitary Sewers	3,300
Storm/Industrial Waste Sewers	1,100

PRIOR YEARS FUNDING:	2,962
Construction	---
Facility Planning and Design	524
Capitalized Investment	2,438

PROJECT DESCRIPTION:
This project is the third of five phases to repair the aging sanitary sewer system. The scope includes replacing sewer mains, eliminating cross connections between sanitary and storm water systems, and repairing/installing oil-water separators. It also includes excavation, backfill, and pavement repair necessary to replace sewer lines and manholes. It will improve the hydraulics of the system, greatly reduce maintenance and operating costs, and eliminate noncompliance discharges to the storm outfalls. Funds will be requested in FY 2002 and 2003 to restore other segments of the sewer system.

PROJECT JUSTIFICATION:
The existing sanitary sewer system is more than fifty years old and is in poor condition. This project will reduce treatment and maintenance costs associated with operating the aging sanitary sewer system and eliminate nonconformance discharges to storm outfalls. This project will reduce maintenance costs by reducing the need for emergency repairs on broken lines. It will reduce treatment costs by reducing inflow and infiltration into the sanitary sewer. In addition, it will eliminate noncompliance discharges to storm outfalls caused by broken sanitary lines and cross connections to comply with National Pollution Discharge Elimination System permits.

IMPACT OF DELAY:
Without the project, avoidable and costly treatment of storm water discharged through the sanitary sewer system will continue. In addition, continued breaks and blockages in sewer lines are likely to occur, requiring costly emergency repairs. Continued noncompliance notices could result in increased inspection, increased monitoring, and fines by the Ohio EPA.

PROJECT TITLE: Repair Site Steam Distribution System, Phase 3
COGNIZANT OFFICE: Office of Earth Science

INSTALLATION: Goddard Space Flight Center
LOCATION: Greenbelt, MD

FY 01 COST ESTIMATE (Thousands of Dollars)	4,000
Project Elements:	
Replace northeast header	1,880
Replace northwest header	880
Replace piping for Bldgs 1, 2, & 13	940
Replace other related piping	300

PRIOR YEARS FUNDING:	7,223
Construction	4,900
Facility Planning and design	285
Capitalized Investment	2,038

PROJECT DESCRIPTION:
This project is the third of five phases to repair major portions of the central steam distribution system at Goddard Space Flight Center (GSFC). The scope includes replacing northeast header, northwest header, and other related piping and insulation. Approximately $7 million will be required in FY 2002/2003 to repair other portions of the site steam distribution system.

PROJECT JUSTIFICATION:
The central steam distribution system was originally installed in the early 1960s and is at the end of its useful life. The system has deteriorated to the point that corrosion is causing pipes to break and valves to leak. Concrete manholes are deteriorated from steam and condensate leakage causing damage to the surrounding landscape and roadway. The site steam distribution system has become undersized due to substantial growth in buildings and related steam demand. The added steam loads on the East Campus require significant upsizing of the main headers. Some condensate and high pressure drip lines have failed. The condensate is piped to drain, resulting in waste of water, energy and treatment chemicals. In addition, the leakage of condensate to ground water is in violation of environmental regulations. Extensive insulation failures have resulted in energy losses and damage to site landscaping and pavement. This project will reduce operation and maintenance costs and enhances reliability as well as the ability to maintain the site steam distribution system.

IMPACT OF DELAY:
A major failure could occur in the campus-wide steam distribution system, resulting in the loss of steam supply to several buildings. This would seriously impact the critical operations in those buildings. The delay will also increase operation and maintenance costs necessary to keep the deteriorated system operational.

PROJECT TITLE: Restore Chilled Water Distribution System, Phase 5
COGNIZANT OFFICE: Office of Earth Science

INSTALLATION: Goddard Space Flight Center
LOCATION: Greenbelt, MD

FY 01 COST ESTIMATE (Thousands of Dollars)	5,000
Project Elements:	
Replacement of NW header from Bldg 24 to Bldgs 18, 19, 20	1,150
Replacement of feed lines to BldgS 4 & 28	1,250
Replacement of eastern loop for Bldgs 16, 12	1,100
Replacement of feed line to Bldg 8, 16, & 19	450
Replacement of line from South Header to Bldg 13	600
Miscellaneous related construction cost	250
Other Costs	200

PRIOR YEARS FUNDING:	25,068
Construction	13,071
Facility Planning and Design	400
Capitalized Investment	11,597

PROJECT DESCRIPTION:
This project is the fifth of seven phases to replace major portions of the GSFC chilled water distribution system. The scope includes replacing part of the northwest header from Building 24 to Buildings 18, 19, 20; feed lines to Building 4; the feed line to Building 28 and its interconnection with the Buildings 18, 19, 20 header; part of the eastern loop for Buildings 16 and 12, including the feed line to Building 12; feed line to Building 8; feed line to Building 19; feed line to Building 16; and the line from the South header to Building 13. Approximately $3 million will be required in FY 2002 to restore other segments of the chilled water distribution system.

PROJECT JUSTIFICATION:
GSFC has experienced serious hydraulic problems with the chilled water distribution system. The campus-wide 30-year-old chilled water distribution system has deteriorated with age and become undersized due to substantial growth in buildings and related chilled water demand at GSFC. This is causing inadequate flow and pressure in the chilled water distribution system in various buildings, pipe breaks, inoperable valves, and other similar problems. Many sections of piping do not have shut off valves. The new lines will improve reliability and cooling conditions in several buildings.

IMPACT OF DELAY:
Delay of this project will result in continued leaking and failures due to old piping and increasing pressures. Some of the system will experience flow deficiencies unless pipe sizes are increased. As a result, several buildings will have inadequate chilled water quantities and air conditioning capacity causing shutdown of mission critical and technical support operations. The delay will also increase operation and maintenance costs required to keep the deteriorated system operational.

PROJECT TITLE: Replace Chillers, Space Flight Operations Facility
COGNIZANT OFFICE: Office of Space Science

INSTALLATION: Jet Propulsion Laboratory
LOCATION: La Canada-Flintridge, Los Angeles County, CA

FY 01 COST ESTIMATE (Thousands of Dollars)	1,800
Project Elements:	
Sitework	100
Architectural/Structural	150
Mechanical	1,250
Electrical	300

PRIOR YEARS FUNDING:	18,954
Construction	---
Facility Planning and Design	108
Capitalized Investment	18,846

PROJECT DESCRIPTION:
This project replaces three old, inefficient 500,000-ton air conditioning water chillers and related equipment in the Space Flight Operations Facility, Building 230. The three new 350,000-ton replacement water chillers will be state-of-the art, high efficiency units that comply with Southern California Air Quality Management District (SCAQMD) standards utilizing an environmentally acceptable refrigerant. The aging, maintenance intensive, chilled water pumps will be replaced with pumps that match the new chillers and the building's requirements. Special accommodations will be made to provide alternate cooling capacity to keep this very critical building in operation during this construction project.

PROJECT JUSTIFICATION:
It is essential that the chillers for this building be reliable because they provide cooling capacity for the computers that help to control all of NASA's deep space missions. The chillers in this building will be over twenty years old at the time of replacement. The chillers are unreliable because repairs have become more frequent and expensive to accomplish. One chiller takes an inordinate amount of time to start and tends to self-trip off when running. Another Chiller has corrodedcreating plugged and leaking tubes that require frequent maintenance and replacement. Because new computers require less electrical power and produce less heat, the chillers are not operating in their peak efficiency range. This shortens their useful life and makes them more susceptible to maintenance problems. Replacing the three 500 ton chillers with three 350-ton units will significantly lower energy consumption and the need for frequent repairs. The high usage of the mission control center severely constrains the scheduling of repair work and results in much higher costs for the repairs.

IMPACT OF DELAY:
Delay of this project results in continued risk of chiller failure and inefficient system operation. This wastes energy and increases costs. A lengthy outage caused by failure of the chillers would interrupt Deep Space Network support to flight projects, pose a safety hazard to personnel, and result in extensive damage to equipment.

PROJECT TITLE: Upgrade 34-Meter Beam Waveguide Antenna Subnet for Ka-Band
COGNIZANT OFFICE: Office of Space Science

INSTALLATION: Jet Propulsion Laboratory
LOCATION: Goldstone, CA; Canberra, Australia; and Madrid, Spain

FY 01 COST ESTIMATE (Thousands of Dollars)	1,900
Project Elements:	
Azimuth and Elevation Encoder Mounting	300
Pedestal & Shroud Modifications	220
Antenna Alidade Modifications	1,380

PRIOR YEARS FUNDING:	46,250
Construction	---
Facility Planning and Design	111
Capitalized Investment	46,139

PROJECT DESCRIPTION:
This project modifies the 34M Beam Waveguide (BWG) Antennas in the Deep Space Network (DSN) to support the implementation of Ka-Band. The project entails removing and replacing the current 32-segment azimuth encoder gear rack with a one piece gear rack. Also included are the azimuth encoder mounting and encoder assembly cover; removing and replacing the elevation encoder mounting hardware and flexible couplings; installing insulation and weather shield to critical members of the alidade structure; and modifying the pedestal radio frequency shroud to allow installation of the Ka-Band feed system.

PROJECT JUSTIFICATION:
The DSN is committed to support multiple deep space projects whose data rates require the added capability of Ka-Band reception. This capability has been implemented at a single station (DSS-25) and the design and operation was verified by using the modification with the Deep Space-1 Project. One of the first missions that will require this capability is a Europa lander. To operate onKa-Band the Antennas must operate under very stringent pointing requirements, which in turn, requires modifications to pedestal, alidade, encoder mounting and associated facility portions of the antennas. Ka-Band will provide larger amounts of command and control guidance to flight hardware in less time.

IMPACT OF DELAY:
This project is required to meet the communications data load requirement for the growing number of planned deep space missions in a cost effective and efficient manner. If this project is not accomplished, then the Deep Space Network will be unable to support future spacecraft missions currently planned to operate using Ka-Band frequencies. Construction of additional antennas at much higher cost would be needed to accommodate the scheduled increase in data load. Without adequate support from the DSN, the deep space missions will be unable to download all the valuable data that each mission is intended to collect.

PROJECT TITLE: Rehabilitate Electrical Distribution System, 200 Area
COGNIZANT OFFICE: Office of Space Flight

INSTALLAION: White Sands Test Facility
LOCATION: Las Cruces, Dona Ana County, NM

FY 01 COST ESTIMATE (Thousands of Dollars):	2,500
Project Element:	
Transformers and Protective Devices	370
Switchgear	600
Interconnecting Systems	640
Concrete Foundations	65
Motor Control Center	625
Power Conditioning Devices	70
Miscellaneous	130

PRIOR YEARS FUNDING:	695
Construction	---
Facility Planning and Design	200
Capitalized Investment	495

PROJECT DESCRIPTION:
This project rehabilitates the electrical distribution system located at the 200 Area of the White Sands Test Facility (WSTF). Electrical distribution and utilization interface equipment and interconnecting wiring systems will be replaced or modified to provide maintenance bypass circuits, fault protection circuits, load management control, and modern equipment protection. Utilization interface work includes replacing or installing panel boards, load centers, circuit breakers, transformers, power con- ditioners, and phase protection; reconfiguring circuits to match user requirements; & installing databased load and configuration management system. Distribution work includes replacing and installing 25,000-volt pad mounted distribution transformers and terminal enclosures, lightning arresters, terminations, switchgear, interconnecting wiring and raceway systems, and foundations.

PROJECT JUSTIFICATION:
This project is required to assure continued, reliable, and safe electrical supply to the WSTF technical service areas and test facilities, including component and assembly test areas, clean rooms, chemistry labs, photo/video areas, and supporting offices and equipment. The existing electrical systems and substation will have been in continuous service in excess of 35 years and can no longer support all building expansions and other ad hoc modifications made over the years. The systems have limited fault protection circuits, are marked by numerous failures, and their capacity and flexibility are marginal. Replacement components necessary to maintain continued use of existing obsolete equipment which is no longer available from the original manufacturer. Consequently, replacement parts are costly and cannot be obtained in a timely manner. The systems have no efficient way of accommodating modifications or supporting additional loads. Special circuits and transient voltage protection systems are required to minimize power fluctuations that damage sensitive electronic equipment. Fault protection and maintenance bypass circuit modifications are required to provide added isolation of areas in emergency situations.

IMPACT OF DELAY:
Continued operation of unreliable and unsafe electrical equipment risks injury to personnel and damage to property in the affected buildings and test areas. Failure of this substation or its ancillary electrical equipment is likely at any time and would cause prolonged disruptions to testing and other operational activities. Operations and maintenance costs would stay excessively high. Personnel maintaining antiquated and unsafe equipment would continue to do so at risk of injury.

PROJECT TITLE: Construct Operations Support Building, Hypergol Maintenance Facility INSTALLATION: Kennedy Space Center
COGNIZANT OFFICE: Office of Space Flight LOCATION: Brevard County, Merritt Island, FL

FY 01 COST ESTIMATE (Thousands of Dollars):	3,300
Project Element:	
Site Work and Utilities	350
Architectural and Structural	1,750
Mechanical	650
Electrical	550

PRIOR YEARS FUNDING:	330
Construction	---
Facility Planning and Design	330
Capitalized Investment	---

PROJECT DESCRIPTION:
This project constructs an Operations Support Building in the Hypergol/Payload Test Area. The facility will be approximately 19,000 square feet and accommodate approximately 100 workers. The new facility will consist of offices, training rooms, computer rooms, technical documentation storage, miscellaneous support areas, and storage. Facility systems to be included are heating, ventilation, and air conditioning (HVAC); power; natural gas; water; sewage; fire detection and protection; and paging and area warning systems. The project will also upgrade the existing central utilities and control systems in order to support the new facility. Non-construction funding in the amount of $250,000 will be budgeted to outfit and activate the facility.

PROJECT JUSTIFICATION:
This project replaces approximately 17,000 square feet of grossly substandard workspace used by approximately 100 people supporting hazardous operations in the Hypergol/Payload Test Area. The substandard workspace consists of two deteriorated 35-year-old buildings (M7-961 and M7-1061, approximately 7,000 square feet) that are functionally inadequate and not economically viable to repair, and fifteen 20-year old dilapidated trailer units (approximately 10,000 square feet) with an original design-life of about six years. The workspace is required to enable timely and reliable turnaround testing of the Orbiter Aft Propulsion System (APS) and Forward Reaction Control System (FRCS) hazardous hypergolic propulsion and steering thrust modules.

The extreme state of disrepair of the existing facilities and trailers is contributing to intensive and unscheduled maintenance having excessive costs; highly inefficient and costly energy consumption; and working environments that barely meet minimum safety and health standards for occupancy. Trailers and modular buildings at KSC have 24 times more environmental health complaints than comparable permanent facilities at KSC. This project is essential to assure a safe and healthful working environment for engineers and technicians performing hazardous operations work.

IMPACT OF DELAY:
People would continue to work in deteriorated substandard facilities, which adversely affects morale and productivity, and could potentially compromise the safety of personnel, property, and critical flight hardware. Operations and maintenance costs and energy consumption would stay excessively high. Productivity would continue at lower levels also because people working on the same activities are not in close proximity to each other.

PROJECT TITLE: Construct Operations Support Building, Pad B
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Kennedy Space Center
LOCATION: Brevard County, Merritt Island, FL

FY 01 COST ESTIMATE (Thousands of Dollars):	4,000
Project Element:	
Site Work and Utilities	420
Architectural and Structural	2,100
Mechanical	800
Electrical	680

PRIOR YEARS FUNDING:	320
Construction	---
Facility Planning and Design	320
Capitalized Investment	---

PROJECT DESCRIPTION:
This project constructs an Operations Support Building in the Launch Complex 39, Pad B Area. The facility will be approximately 25,000 square feet, and accommodate approximately 100 technicians and engineers that provide 3-shift processing support. The new facility will be of permanent masonry construction and will have offices, training rooms, and technical documentation storage. Facility systems to be included are heating, ventilation, and air conditioning (HVAC); power; natural gas; water and sewage; fire detection and protection; and paging and area warning systems. The project will also upgrade the existing central utilities and control systems in order to support the new facility. Non-construction funding in the amount of $1.5 million will be budgeted to provide for systems furniture, communication systems, computer equipment, and other such outfitting and activation costs.

PROJECT JUSTIFICATION:
This project replaces approximately 40 temporary boxcar units (approximately 22,000 square feet) used to provide operations support space for approximately 100 workers supporting launch pad processing, and test and checkout operations. The substandard workspace consists of 50-year-old railroad boxcars that were modified and converted to office use almost 20 years ago. The heavy salt corrosive environment of Florida's Atlantic coast has aggressively attacked and severely corroded these now dilapidated boxcars. The units have exceeded their intended useful service life due to significant structural degradation and have become maintenance intensive. The severe state of degradation of these facilities creates a poor workplace environment that adversely affects worker morale and productivity and could potentially affect their safety and health. Trailers and modular buildings at KSC have 24 times more environmental health complaints than comparable permanent facilities at KSC. The extreme state of disrepair of these boxcars is contributing to intensive and unscheduled maintenance having excessive costs; highly inefficient and costly energy consumption; and working environments that barely meet minimum safety and health standards for occupancy. This project is essential to assure a safe and healthy workplace environment for engineers and technicians performing critical operations work affecting timely and reliable launch of the Space Shuttle.

IMPACT OF DELAY:
People performing day-to-day shift support would continue to work in deteriorated substandard facilities, which adversely affects their morale and productivity, and could potentially affect their health and safety. Operations and maintenance costs and energy consumption would stay excessively high. Productivity would continue at lower levels also because people working on the same activities are not in close proximity to each other.

PROJECT TITLE: Construct Operations Support Building II, LC-39 Area , Phase 1 INSTALLATION: Kennedy Space Center
COGNIZANT OFFICE: Office of Space Flight LOCATION: Brevard County, Merritt Island, FL

FY 01 COST ESTIMATE (Thousands of Dollars):	13,000
Project Element:	
Site Work and Utilities	3,000
Architectural and Structural	7,000
Mechanical	2,000
Electrical	1,000

PRIOR YEARS FUNDING:	2,400
Construction	---
Facility Planning and Design	2,400
Capitalized Investment	---

PROJECT DESCRIPTION:
This project provides for the construction of a second Operations Support Building in the LC-39 Vehicle Assembly Building (VAB) area. The complex will be approximately 200,000 square feet and accommodate approximately 1,000 workers. The complex will support operational areas and consist of offices, training rooms, computer rooms, multi-media conference rooms, Mission Conference Center with observation deck, technical libraries, Exchange storage, snack bar, storage, miscellaneous support areas, and parking. Facility systems to be included are heating, ventilation, and air conditioning (HVAC); power; natural gas; water; sewage; fire detection and protection; and paging and area warning systems. The project will also upgrade the existing central utilities and control systems in order to support the new complex. A second and final phase estimated at $7 million is required in FY 2002 to complete this facility, bringing the total estimated construction cost to $20 million. Non-construction funding in the amount of $14 million will be budgeted to provide for systems furniture, communication systems, computer equipment, and other such outfitting and activation costs.

PROJECT JUSTIFICATION:
A critical need exists in the LC-39 VAB Area to eliminate 280 trailer equivalents of dilapidated substandard housing affecting the safety, morale and welfare of approximately 700 Shuttle processing workers, transient Launch fallback personnel, and personnel who attend training. Completion of this project will also allow consolidation of fragmented programs affecting approximately 300 workers currently scattered across the Center supporting Launch Complex 39 operations and Spaceport Technology Center strategies. This consolidation will enable KSC to eliminate additional substandard housing when the vacated permanent housing currently being used by the fragmented programs is backfilled.

The heavy salt corrosive environment of Florida's Atlantic coast has aggressively attacked and severely corroded the existing facilities which consist of 20-year-old portable office trailers and modified railroad boxcars. These facilities have mold and indoor air quality problems; siding and floor substructures that are rotting and termite infested; roof and siding that are leaking water; plumbing that does not drain properly; tripping hazards, such as uneven floors and exterior stairs that are wobbly and unstable; and numerous other code violations. Trailers and modular housing at KSC have 24 times more environmental health complaints than comparable permanent facilities at KSC. This situation is contributing to intensive and unscheduled maintenance having excessive costs; highly inefficient and costly energy consumption; and working environments that barely meet minimum safety and health standards for occupancy.

IMPACT OF DELAY:

People would continue to work in deteriorated substandard housing, which adversely affects morale and productivity. Maintenance would continue to cost approximately $1.3 million/year more than for conventional permanent facilities and 47% more energy would continue to be consumed. Productivity would continue at lower levels also because people working on the same program are not in close proximity and have to travel greater distances.

PROJECT TITLE: Repairs to Primary Electrical Power System
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Kennedy Space Center
LOCATION: Brevard County, Merritt Island, FL

FY 01 COST ESTIMATE (Thousands of Dollars):	3,500
Project Element:	
Demolition	250
New Transformers	1,200
New Circuit Breakers	1,450
Emergency Feeder	350
Bus Structural Modifications	250

PRIOR YEARS FUNDING:	19,446
Construction	---
Facility Planning and Design	150
Capitalized Investment	19,296

PROJECT DESCRIPTION:
This project repairs critical components of the primary electrical power system at KSC. The project replaces transformers and oil circuit breakers at the Orsino primary substation; replaces oil circuit breakers at the C-5 primary substation; and replaces the Utility Annex Emergency Power diesel-generator system with a substation direct feeder.

PROJECT JUSTIFICATION:
This project is essential to assure safe and reliable electrical power for KSC launch operations; payloads, shuttle, and space station processing; and administration and engineering support activities. The repairs to the Orsino and C-5 primary substations will modernize and improve the safety and reliability of the primary electrical power infrastructure at KSC. The modifications to the Utility Annex Emergency Power System will overcome an existing diesel startup time-deficiency. All work to be accomplished by this project is required to achieve compliance with fire and life safety codes.

System components and equipment at all locations exceed 30-year design life expectancy. Spare parts are difficult and costly to obtain in a timely matter because they are no longer in production. The Orsino Substation transformers present a fire hazard condition because they do not meet Fire Code minimum installation clearances. The existing 15 kV class oil circuit breakers present a safety hazard to maintenance personnel because they do not meet National Electrical Code minimum installation clearances between high voltage parts and electrical ground. The Utility Annex uses a diesel generator for emergency power that does not satisfy the Life Safety Code criteria for start-up within 10 seconds after loss of primary power.

The Orsino substation supplies electrical power for the Industrial Area Administration and Engineering Support Buildings; the Operations and Checkout Facility; the Hypergol Maintenance Facility; the Payloads Test Area; the Space Station Processing Facility; and the Industrial Area Chiller Plant. The C-5 Substation and its Utility Annex Emergency Power System supplies electrical power for critical Shuttle processing/launch activities in the Vehicle Assembly Building area and LC-39 launch complex.

IMPACT OF DELAY:
Continued operation of unreliable and unsafe electrical equipment at KSC increases the risk of injury to personnel, damage to property, and interruption of payload processing and launch operations. Operations/maintenance costs would stay excessively high. Personnel maintaining antiquated and unsafe oil circuit breakers would continue to do so at risk of severe injury.

PROJECT TITLE: Repairs to Electrical Systems, East and West Areas
COGNIZANT OFFICE: Office of Aero-Space Technology

INSTALLATION: Langley Research Center
LOCATION: Hampton, VA

FY 01 COST ESTIMATE (Thousands of Dollars)	9,000
Project Elements:	
WP 1 - Substation Electrical Repairs (642 & 1233)	2,400
WP 2 - Electrical Repairs (1265 & 1273A)	950
WP 3 - Electrical Repairs (1152, 1201, 1209, & 1219)	550
WP 4 - Electrical Repairs (1221, 1236, 1239, & 1247B)	2,400
WP 5 - Electrical Repairs (1251 & 1267A)	2,700

PRIOR YEARS FUNDING:	4,525
Construction	---
Facility Planning and Design	577
Capitalized Investment	3,948

PROJECT DESCRIPTION:
This project repairs and replaces the major portions of the Langley Research Center's (LaRC) High Voltage Power System. The project is required to assure continued reliability and safe electrical power supply at LaRC. The system distributes power to all of the Center's aerospace research and development facilities, the computer center, and institutional facilities. This project replaces various oil circuit breakers and transformers at the Back River Substation (B642) and Stratton Substation (B1233), and it replaces various equipment including circuit breakers, transformers, and switchgear in the unit substations at Buildings 1265, 1273A, 1236, 1152, 1201, 1209, 1219, 1239, 1221, 1247B, 1251, and 1267A.

PROJECT JUSTIFICATION:
The high voltage power system provides power to all the aeronautics and aerospace Research and Development facilities to support major research programs. It is over 50 years old with obsolete circuit breakers, switchgear, and transformers that are practically impossible to maintain causing frequent and costly emergency repairs each year. Failure of existing circuit breakers is imminent and could result in a 6 to 12-month shutdown of research facilities. Economic analysis indicates this project is the most cost-effective approach to maintain an operating system for the next 25 years.

IMPACT OF DELAY:
Failure rates currently being experienced will increase if repairs to the high voltage power system are delayed. Major disruptions of electrical services, associated with single point failures, are anticipated. These failures will result in the shutdown of critical research facilities and the programs they support for periods up to 12 months.

PROJECT TITLE: Repair and Modernize Fluid Dynamics Vacuum Pump Facility
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Marshall Space Flight Center
LOCATION: Madison County, AL

FY 01 COST ESTIMATE (Thousands of Dollars):	2,600
Project Element:	
Architectural and Structural	375
Mechanical	1,700
Electrical	525

PRIOR YEARS FUNDING:	310
Construction	---
Facility Planning and Design	260
Capitalized Investment	50

PROJECT DESCRIPTION:
This project replaces the vacuum pumping system of the Fluid Dynamics Vacuum Pump Facility (Building 4734) with a modern fully automated system of similar configuration, but with upgraded capabilities. The new pumps will have a pumping capacity of approximately 13,200 cubic feet per minute at atmospheric pressure and will be capable of achieving an ultimate vacuum of 0.39 inches (10 millimeters) of mercury in 15 minutes. The vacuum field consists of six 7,000-cubic-foot vessels for a total capacity of 42,000 cubic feet. All motors, piping, and associated components will be repaired or replaced. Supporting infrastructure will be upgraded to accommodate the new vacuum pumping system and to bring the facility into compliance with latest Life-Safety and Building codes. The project also provides for a 5-ton crane and a covered walkway between Building 4732 and Building 4734.

PROJECT JUSTIFICATION:
The Fluid Dynamics Vacuum Pump Facility supplies a Trisonic Wind Tunnel (TWT) in Building 4732, which is vital for MSFC to perform its assigned roles and missions. This project restores lost vacuum pumping capability, reduces time required to obtain required vacuum pressures, increases/conserves test time, and improves overall effectiveness and performance of the TWT. Presently one fourth of the pumping capability is inoperable. Spare parts cannot be obtained, and the individual pumps cannot be replaced in-kind because they are obsolete and no longer in production. The time needed to obtain the required vacuum conditions in the TWT is excessive. This project replaces the pumps and motors in Building 4734 in order to reduce the time needed to obtain required vacuum conditions, improve reliability, and reduce maintenance costs. The new pumping modules will be optimized to provide maximum efficiency and flexibility of operation. The waste oil containment system will be upgraded to improve operational efficiency. Workspace and clearances around equipment currently do not comply with the mandated requirement of the National Electrical Code for assuring safe access for service and maintenance personnel. This project corrects this non-compliance and also provides improved equipment replacement routes to accommodate equipment change-out during service and maintenance operations. The old controls for the TWT vacuum system will be replaced to conserve test time.

IMPACT OF DELAY:
Twenty-five percent of the pumps at this facility are already inoperable and additional pump failures are highly likely in the near future. A delay of this project puts the TWT at high risk of a further reduction in testing capability. Continued operation of this facility without the benefits of the proposed efficiency and performance upgrades will greatly impact progress of multiple on-going research and development activities and continue to drain scarce operations and maintenance resources.

PROJECT TITLE: Replace Roof, Building 4705, Phase 2
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Marshall Space Flight Center
LOCATION: Madison County, AL

FY 01 COST ESTIMATE (Thousands of Dollars):	2,400
Project Element:	
Architectural and Structural	2,170
Mechanical	185
Electrical	45

PRIOR YEARS FUNDING:	8,356
Construction	1,000
Facility Planning and Design	137
Capitalized Investment	7,219

PROJECT DESCRIPTION:
This project replaces the roof systems adjoining the main high bay roof of Building 4705. Work includes replacing roofing east, west, and north of the main high bay roof (Sections B, D, E1, N2, N, O, P, Q, R, S, M, K, H2, T, J, H1) with a blue standing seam metal roof system. A light gauge metal framing system will be built up and attached to the existing major roofing structural members to provide a minimum roof slope. New flashing, gutters, strainers, and down spouts will be installed to make the roof watertight. Modifications will be made to roof mounted mechanical system components and roof penetrations, as required, to accommodate the work.

PROJECT JUSTIFICATION:
The purpose of this project is to alleviate existing roofing problems resulting from years of seasonal weathering. The roof of this facility, which houses portions of the Materials, Processes and Manufacturing Department, is in need of total repair due to age and deterioration. The normal roof life expectancy at MSFC is 25 years. The roof of Building 4705 (built in 1955) has far exceeded its useful life. This project is required to alleviate leaks and other deficiencies; to improve and extend roof system reliability to protect mission support activities; and to reduce the roofing maintenance backlog.

The primary functions of the facility are welding sensor and robotic welding development, sheet metal assembly, and precision cleaning. The facility has clean rooms for processing experimental and flight hardware. Through these functions, the facility supports all NASA Strategic Enterprises. A project to replace the adjacent main high bay roof was funded in FY 2000. This FY 2001 project addresses the surrounding/adjoining roof areas. Repair of the roof sections east, west, and north of the main high bay is essential to protect and preserve facility capability and to remove the threat of unscheduled interruptions to development and simulation operations.

IMPACT OF DELAY:
A delay of this project would allow the existing roof to degrade to failure, putting the weather integrity of the structure at risk. The future cost of this work would then be significantly higher. Progressively higher water intrusion rates would occur, which would impact development functions and activities of the facility users. These higher water intrusion rates would also risk damage to experimental and flight hardware, and to the interior of the building. The high frequency and excessive cost of maintenance would continue to increase.

PROJECT TITLE: Replace Mechanical Equipment and Roof, Building 350
COGNIZANT OFFICE: Office of Space Flight

INSTALLATION: Michoud Assembly Facility
LOCATION: New Orleans, Orleans Parish, LA

FY 01 COST ESTIMATE (Thousands of Dollars):	5,800
Project Element:	
Architectural and Structural	4,150
Mechanical	1,475
Electrical	175

PRIOR YEARS FUNDING:	9,158
Construction	---
Facility Planning and Design	458
Capitalized Investment	8,700

PROJECT DESCRIPTION:
This project replaces the roof of Building 350. The roof replacement entails removing the ballast, installing foam insulation, applying lightweight cement, installing a 2-ply roofing system, and extending the drain downspout to the sloped roof. This project also replaces selected chillers and boilers that service Building 350 although they are physically located in the Building 351 equipment room. Two chillers (2,100-kilowatt each) will be replaced with one chiller of 4,300-kilowatt nominal capacity. A steam boiler and a hot water boiler will be replaced in kind.

PROJECT JUSTIFICATION:
This project eliminates existing roofing problems resulting from 23 years of seasonal weathering. The roof exhibits widespread bare and soft spots, blisters, open laps, felt deterioration, and rusting of the metal components typical of a roof that has reached the end of its useful life. The building has already experienced leaks in several areas and has numerous point repairs. This project eliminates leaks and other deficiencies; improves and extends roof system reliability; and reduces the roofing maintenance backlog.

The two chillers service Buildings 350 and 351 and have been in service since 1980. These chillers have numerous refrigerant leaks, plugged and severely corroded tubes, corrosion of shell wall thickness to one-half original specification, and obsolete starter parts requiring workarounds or custom-made parts. The two boilers also have major deficiencies, such as leaking tubes that have reduced capacity causing a loss of operational efficiency; pitting on internal surfaces causing heat transfer loss and metal fatigue; and deteriorating refractory causing hot spots on the metal outer shell and a major loss of energy. Neither the chillers nor the boilers can meet the current load requirements of Building 350 and 351 because of their deteriorated state.

IMPACT OF DELAY:
A delay of this project would allow the existing roof to degrade to failure, putting the weather integrity of the structure at risk. The future cost to repair would then be significantly higher. Progressively higher water intrusion rates would also risk damage to indoor mainframe computers as well as to the interior of the building. The high frequency and excessive cost of maintenance would continue to increase. The chillers and the boilers are in such state of deterioration that they are likely to fail at any time in the near future. A failure of one of the chillers would create costly lost time disruptions due to the loss of necessary cooling capacity required to support both personal and mainframe computer usage in Building 350. Likewise, a failure of either one of the boilers would result in closure of Building 350 due to lack of building heat, or closure of the cafeteria operations in Building 351 due to loss of hot water.

PROJECT TITLE: Repair Storm Drainage System, Phase 1
COGNIZANT OFFICE: Office of Earth Science

INSTALLATION: Wallops Flight Facility
LOCATION: Wallops Island, VA

FY 01 COST ESTIMATE (Thousands of Dollars)	2,700
Project Element:	
Clean, repair and line storm sewer	2,700

PRIOR YEARS FUNDING:	14,286
Construction	---
Facility Planning and Design	125
Capitalized Investment	14,161

PROJECT DESCRIPTION:
This project provides for replacing, lining and joint grouting 6,600 feet (2,000 meters) of the 50-year-old storm drainage piping system. The pipe sizes vary from 12 inches to 60 inches (305 millimeters to 1525 millimeters). The repair of associated catch basins and manholes is also included. Approximately $4.5 million will be required to repair the remaining segments of the storm drainage system.

PROJECT JUSTIFICATION:
This work is required to repair deteriorated storm drains located in an area with a high water table. The storm drainage system is 50 years old and eroding at the pipe joints. Video inspection of the interior of storm drainage pipes has revealed evidence of extensive cracking and failing pipes. In 1999, the failure of one of the deteriorated storm pipes located under Runway 10/28 caused erosion of the subgrade material around the pipe. This led to an almost immediate differential settlement of the runway pavement resulting in a large depression in the surface that imperiled aircraft operations. The work must be accomplished to prevent additional system deterioration that would undermine roads, taxiways and runways, thereby increasing the threat to personnel safety, aircraft and facilities.

IMPACT OF DELAY:
Delaying the rehabilitation of remaining pipes perpetuates the increasingly unacceptable risk of future failures, which could endanger aircraft and flight personnel.

PROJECT TITLE: Minor Revitalization and Construction of Facilities, Not in Excess of $1,500,000 Per Project
COGNIZANT OFFICE: Office of Management Systems LOCATION: Various

	Mission Support	Human Space Flight
FY 01 COST ESTIMATE (Thousands of Dollars)	106,800	9,400
Location:		
Ames Research Center	10,225	
Dryden Flight Research Center	4,900	
Glenn Research Center	7,825	
Goddard Space Flight Center	7,050	
Jet Propulsion Laboratory	11,050	
Johnson Space Center	22,400	1,200
Kennedy Space Center	14,200	6,800
Langley Research Center	7,100	
Marshall Space Flight Center	10,850	
Stennis Space Center	11,200	1,400

PROGRAM DESCRIPTION:
Proposed projects for FY 2001 are identified under "MINOR PROJECT COST ESTIMATE". They include Mission Support projects totaling $106.8 million for components of the basic infrastructure and institutional facilities, and $9.4 million to accomplish specific Human Space Flight projects. The $9.4 million is included in the appropriate budget line items of the Human Space Flight appropriation. The cost estimates are shown here to provide a complete picture of NASA's budget requirement for facilities.

These resources provide for revitalization and construction of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. The request includes facility revitalization and construction needs for FY 2001 that are greater than $500 thousand but not in excess of $1.5 million per project. Revitalization projects provide for the repair, modernization, and/or upgrade of facilities and collateral equipment. Repair and modernization projects restore facilities and components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. Repair and modernization work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. It also includes major preventive measures that are normally accomplished on a cyclic schedule. Upgrade projects may include not only some restoration of current functional capability, but also enhancement of the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability. Occasionally minor facility construction projects will be required to provide for either the construction of small new facilities or additions to existing facilities. The facilities being revitalized or constructed in this program are expected to remain active in the long term and are

consistent with current and anticipated Agency roles and missions. Annual funding will be required for continuing minor revitalization and construction needs.

This program includes revitalization and construction projects estimated to cost more than $500 thousand per project. Projects $500 thousand and less in magnitude are normally accomplished by routine day-to-day facility maintenance and repair activities provided for in Human Space Flight; Science, Aeronautics and Technology; and Mission Support appropriations. Projects estimated to cost more than $1.5 million are included as separate discrete projects in the budget request.

PROGRAM JUSTIFICATION:
NASA is experiencing "block obsolescence" because 90% of the agency's facilities have been in use for over 25 years. Repair costs for mechanical and electrical systems in a typical building are almost three times higher after system operations exceed 15-20 years than they are during the initial years. Many electrical and mechanical components reach the end of their serviceable or economic life at the 20-year point and should be replaced. Continued piecemeal repair of these components is more costly in the long run than replacement at the end of the economic life of the original components.

The NASA physical plant has a capital investment of $6 billion and has a current replacement value of more than $20 billion. A continuing program of revitalization of these facilities is required to accomplish the following:

a. Protect the capital investment in these facilities by minimizing the cumulative effects of wear and deterioration.
b. Ensure that these facilities are continuously available and that they operate at peak efficiency.
c. Improve the capabilities and usefulness of these facilities and thereby mitigate the effects of obsolescence.
d. Provide a better and safer environment for all personnel.
e. Reduce current operating costs and avoid significantly greater future repair costs.

New construction will primarily replace substandard facilities in cases where it is more economical to demolish and rebuild than it is to restore. Included are projects that replace old and dilapidated railroad box cars, trailers, and other modular facilities that do not meet current occupational health and safety standards, and which no longer satisfy user functional requirements. In selected cases, additional square footage may be built when there are compelling reasons to support specialized requirements of a nature that cannot be provided for using existing facilities. Included in this latter category are technical, programmatic, and institutional projects that are essential to the accomplishment of an installation's mission objectives.

MINOR PROJECT COST ESTIMATE (Thousands of Dollars):
The projects that comprise this request are of the highest priority based on relative urgency and expected return on investment. Deferral of this mission-essential work would adversely impact the availability of critical facilities and program schedules. The titles of the projects are designed to identify the primary intent of each project and may not always capture the entire scope or description of each project. Also, during the year, some rearrangement of priorities may be necessary which may force a change in some of the items to be accomplished. Any such changes, however, will be accomplished within total the resources available.

HUMAN SPACE FLIGHT	9,400
A. Johnson Space Center (JSC)	1,200
1. Replace Roof, Building 150, Palmdale, CA	1,200
B. Kennedy Space Center (KSC)	6,800
1. Rehabilitate High Pressure Distribution Piping System, LC-39A	1,500
2. Rehabilitate High Pressure Distribution Piping System, LC-39B	1,500
3. Restore Low Voltage Power System, LC-39A, Phase I	1,500
4. Restore Low Voltage Power System, LC-39B, Phase I	1,500
5. Repair and Modernize HVAC and Emergency Exhaust System, Spacecraft Assembly Encapsulation Facility, Building M7-1210	800
C. Stennis Space Center (SSC)	1,400
1. Repair and Modernize Space Shuttle Main Engine A-2 Test Stand, Phase 2	1,400
MISSION SUPPORT	106,800
A. Ames Research Center (ARC)	10,225
1. Replace Transformer T-44	1,400
2. Repair Variable Pitch Mechanism Splines, National Full-scale Aerodynamics Complex (NFAC) [N221]	1,500
3. Replace Arc Jet Pumps and Electric Motors	1,400
4. Modify Building 19 for Seismic and Fire Safety	1,400
5. Rehabilitate and Modify 20 Megawatt DC Power Supply, Phase III [N234/238]	800
6. Rehabilitate and Modify N227 for Fire Suppression/Alarm Systems	650
7. Add No-Load Break Switches, National Full-scale Aerodynamics Complex [N221] and Unitary Plan Wind Tunnel (N227)	1,000
8. Modify N221 for Exit Stairway and N213 for Basement Exit for Safety Egress	1,000
9. Fire Protection Egress Modifications and Crane Upgrades, Various Facilities	1,075
B. Dryden Flight Research Center (DFRF)	4,900
1. Rehabilitate and Modify Flight Loads Laboratory	1,400
2. Life Safety Repairs, 12.47KV System	950
3. Rehabilitate and Modify Fire Alarm & Suppression, Various Buildings	1,450
4. Rehabilitate and Modify Ductbank Infrastructure	1,100

C. Glenn Research Center (GRC)	7,825
1. Replace CO2 Tanks & Repair High Pressure Steam Lines, Various Buildings	1,125
2. Repair Basement Slab, Space Power Facility Test Building 1411, Plum Brook Station (PBS)	1,400
3. Rehabilitate Model Fabrication and Instrument Facility (14)	900
4. Repair Natural Gas System	700
5. Repair Underpass Road Bridges	700
6. Rehabilitate Main Cafeteria (15)	700
7. Rehabilitate Clean Rooms, Instrument Research Laboratory (77)	1,400
8. Rehabilitate Cell 31, Research Combustion Laboratory (35)	900
D. Goddard Space Flight Center (GSFC)	7,050
1. Rehabilitate Heating, Ventilation, and Air Conditioning (HVAC) Systems, Building 23	800
2. Consolidate and Upgrade Instrument Technology Center Laboratories, Various Buildings	700
3. Repair Roofs, Various Buildings	1,450
4. Replace Power Panels, Building 4, 5, 7, and 10	550
5. Repair Electrical Rooms 1 & 2 and Replace Load Center Building 26	900
6. Modify HVAC Systems, Various Buildings, WFF	700
7. Modify Multi-Payload Processing Facility [F7], WFF	930
8. Replace Roofs, Building 3, 22, 25, and 29, WFF	1,020
E. Jet Propulsion Laboratory (JPL)	11,050
1. Upgrade Dynamics Test Facility, Environmental Test Laboratory	1,200
2. Upgrade Thermal Vacuum Chamber Controls, Building 144	850
3. Modifications to Applied Mechanics Facility [157]	750
4. Upgrade HVAC Controls, Various Buildings	850
5. Modifications for Logistics and Technical Information, Building 111	800
6. Upgrade Electrical Bank #7	850
7. Replace Generator Switchgear, Building 230	950
8. Modify Fire Alarm System, Various Buildings, Phase V	1,000
9. Upgrade Hydraulic Drive, 26M Antenna, Madrid, Spain	900
10. Refurbish Elevators, Various Buildings	1,100
11. Install Fiber Optic Fire Alarm and Security Communications System	900
12. Modification of Building 111, Southeast Basement	900

F. Johnson Space Center (JSC)	22,400
1. Replace Switchgear and Transformers, Buildings 11 and 35	900
2. Replace Switchgear and Transformers, Building 49	900
3. Replace Switchgear and Transformers, Buildings 7A and 15	900
4. Replace Switchgear and Transformers, Buildings 3 and 422	900
5. Rehabilitate Electrical Distribution System, Various Buildings	1,300
6. Repair Window Ledge Coverings, Various Buildings	900
7. Repairs to Propulsion Test Area Systems, WSTF	600
8. Replace 12KV Switches, Various Facilities	1,200
9. Repair and Upgrade Building Systems, Various Facilities [200 Area], WSTF	1,100
10. Repair and Upgrade Building Systems, Various Facilities [800 Area] WSTF	900
11. Safety Repairs to Street and Parking Lot Lighting System, Phase 2	1,300
12. Repair Low Voltage Panels, Mission Critical Buildings [24 & 30]	1,200
13. Install Electrical Grounding System, Various Buildings, Mall Area	1,500
14. Install Electrical Grounding System, Various Buildings, Remote Locations	500
15. Upgrade Electrical Power and Lighting Panels, Various Buildings	1,400
16. Replace Electrical Lighting Panels, Various Buildings	1,200
17. Repair Electrical Receptacle Panels, Various Buildings	1,300
18. Reconfigure Electrical Panel Circuitry, Various Area	1,100
19. Replace Electrical Bus Systems, Various Buildings	700
20. Replace Uninterruptible Power Supply Batteries, Various Areas	1,250
21. Rehabilitate Fire Protection System, Various Locations, WSTF	1,350
G. Kennedy Space Center (KSC)	14,200
1. Revitalize Electrical Power Distribution System, Industrial Area	1,000
2. Revitalize Secondary Power Systems, Vehicle Assembly Building, Phase 1	600
3. Revitalize Secondary Power Systems, LC-39 Area, Phase 3	900
4. Construct Replacement Housing for Pad A LOX/LH2 Operations Personnel	800
5. Construct Replacement Housing for Orbiter Processing Facility Hazardous Operations Personnel	1,500
6. Repair M7-505 HVAC and Roof, Phase 4	800
7. Replace Vacuum Circuit Reclosers and 15 KV Feeder 606, Phase 2	1,000
8. Repair and Upgrade Lighting and Fire Alarm Systems, Launch Control Center, Phase 2	1,300
9. Install Fall Protection Safety Devices, Various Facilities, LC-39 Area, Phase 3	1,400
10. Upgrade Emergency Lighting Systems, Various Facilities, LC-39 Area	800
11. Install Automatic Fire Sprinkler System, Various Locations, LC-39 Area	1,200
12. Upgrade Central Control Station Fire Monitoring System	1,500

13. Install Pier Scour Protection, Haulover Bridge	500
14. Upgrade Physical Security Countermeasures, Launch Pad 39B	900
H. Langley Research Center (LaRC)	7,100
1. Automation Modifications to 31-inch Mach 10 Tunnel (1251A)	1,400
2. Upgrade Transonic Dynamics Tunnel for Productivity Improvements (648)	1,425
3. Construct Integrated Test Facility	1,425
4. Modifications to 15-inch Mach 6 High Temperature Tunnel (1251A)	1,425
5. Rehabilitate Information Media Center (1152)	1,425
I. Marshall Space Flight Center (MSFC)	10,850
1. Repair and Modernize Electrical and Mechanical Systems [4619], Phase 2	1,500
2. Modifications for Composite Development and Manufacturing Laboratory [4707]	900
3. Repair and Modernize Fire Alarm System, Various Buildings, Phase 2	800
4. Rehabilitate and Modify Utilities Control System	1,350
5. Modifications to High Pressure Flammability Test Cells [4623]	800
6. Electrical and Mechanical Repairs to Buildings 4207, 4567, and 4755	750
7. Replace Elevators, Buildings 4708 and 4755	650
8. Repair Corroded Steel Structures, Various Test Stands	1,000
9. Safety Modifications to Overhead Cranes	500
10. Repairs to Cell P [131], Michoud Assembly Facility (MAF)	1,300
11. Repair Sprinkler Heads [103] MAF	1,300
J. Stennis Space Center (SSC)	11,200
1. Increase Capacity, Sewage Treatment Lagoons	550
2. Repair and Modernize Fire Alarm System, Various Facilities	1,450
3. Repair Pavements, Various Locations	1,100
4. Repair and Modify HVAC System, Environmental Laboratory Building [B-1105 West]	1,100
5. Repairs to Chilled and Hot Water Systems, B-Complex	800
6. Repair and Modify 13.8KV Underground Feeders	800
7. Repair and Modernize Interior Building Systems, Data Acquisition Facility [4995]	700
8. Repair and Modernize Secondary Power Systems, Various Facilities, Phase 2	700
9. Modify Propulsion Test and Support Facilities, E-Complex, Phase 1	800
10. Repair Cryo and High Pressure Fluid Components, Engine Test Complex	500
11. Repairs to Structural and Mechanical Systems, A-1 and B-2 Test Stands, Phase 1	1,200
12. Refurbish High Pressure Water Pump Diesel Engines [B-4400]	1,500

PROJECT TITLE: Facility Planning and Design
COGNIZANT OFFICE: Office of Management Systems

LOCATION: Various

FY 01 COST ESTIMATE (Thousands of Dollars)	15,700
Project Elements:	
Master Planning	400
Sustaining Engineering Support	1,000
Project Planning and Design Activities	14,300

These funds are required to provide for advance planning and design activities; special engineering studies; facility engineering research; preliminary engineering efforts required to initiate design-build projects; preparation of final designs, construction plans, specifications, and associated cost estimates; and participation in facilities related professional engineering associations and organizations as follows:

A. Master Planning 400

The NASA field installation master plans need to be periodically updated. The master plans are essential as reference documents for land use planning, identification of physical relationships of facilities, and proper orientation and arrangement of facilities. The updates reflect as-built condition of facilities and utility systems with emphasis on changes caused by recent facility construction and modifications.

B. Sustaining Engineering Support 1,000

Provisions for facility studies and specific engineering support continue in importance as evidenced in recent years. These efforts are important due to changing trends in construction equipment, materials, and fuels; the operation and maintenance costs for the physical plant; and energy conservation and efficiency. The following items are included:

1. Value Engineering, and Design and Construction Management Studies

Provides for critically important studies to improve the quality and cost effectiveness of NASA's facility components and construction practices, and to ensure that developing technology and industry best practices are incorporated into the agency's construction program. Also provides services necessary to predict and validate facility costs to aid in resources planning and studies to assess design and construction functional management.

2. Facility Operation and Maintenance Studies

Provides for studies and engineering support, where not otherwise provided for, at NASA field installations relative to functional management of maintenance, automated maintenance management systems, and facilities condition assessments. Included in this activity are field surveys to be conducted at selected NASA field installations to evaluate the effectiveness and efficiency of the operations and maintenance management activities, and to identify possible improvements in productivity.

3. Facilities Utilization Analyses

Provides for the analyses of agencywide facilities utilization data covering (1) office and other types of building space; (2) designated major technical facilities; and (3) special studies comparing the utilization of technical facilities which are similar in type or capability, such as wind tunnels. Such analyses provide for (1) insights into and development of better methods of identifying underutilized facilities; (2) improved techniques to quantify level of facilities use; (3) actions to improve facilities utilization; and (4) recommendations regarding consolidation/closure of Agency facilities.

4. Facilities Management Systems

Provides for continued engineering support for the technical updating of NASA's master text construction specifications to reflect the use of new materials, state-of-the-art construction techniques and current references to building codes and safety standards. Also provides engineering support for the Major Facilities Inventory, the Real Property Database and the Facilities Utilization Database systems.

5. Capital Leveraging Research Activities

Provides for modest participation in facilities related professional engineering associations, institutes, and organizations established to bring together major facility owners, contractors, and academia in proven research and study efforts to improve the quality and cost effectiveness of facilities engineering management practices for member organizations. Such organizations include, but are not limited to the Federal Facilities Council of the National Research Council, National Institute of Building Sciences, and the Construction Industry Institute. This also provides for independent research activities to address facility problems unique to NASA.

C. Project Planning and Design Activities 14,300

These resources provide for project planning and design activities associated with Mission Support construction projects. Project planning and design activities for construction projects required to conduct specific Human Space Flight or Science, Aeronautics, and Technology programs or projects are included in the appropriate budget line item.

1. Preliminary Engineering (700)

This estimate provides for preparation of Preliminary Engineering Reports (PERs), investigations, project studies and other pre-project planning activities related to proposed facility projects. Construction of Facilities programs. These reports are required to permit the early and timely development of the most suitable project to meet the stated programmatic and functional needs. Reports provide basic data, cost estimates and schedules relating to future budgetary proposals.

2. Related Special Engineering Support (2,500)

This estimate provides for investigations and project studies related to proposed facility projects to be included in the subsequent Construction of Facilities programs. Such studies involve documentation and validation of 'as-built' conditions, survey/study of present condition of such items as roofing and cooling towers, utility plant condition and operational modes, and other similar field investigations and studies. These studies are required to support long term project development strategies, and project specific designs, cost estimates, and schedules.

3. Design (11,100)

The amount requested will provide for the preparation of designs, plans, drawings, and specifications necessary for the accomplishment of construction projects. Also provides technical and engineering support analyses, designs, and reviews required to verify, confirm and ensure suitability of construction designs within the project cost estimates. This work is associated with construction proposed for the FY 2003 program and with changes to projects proposed for the FY 2002 program. The goal is to obtain better facilities on line earlier at a lower cost.

Total Facility Planning and Design 15,700

PROJECT TITLE: Environmental Compliance and Restoration Program
COGNIZANT OFFICE: Office of Management Systems, Environmental Management Division LOCATION: Various Locations

FY 2001 Cost Estimate (Thousands of Dollars)	41,000
Location:	
Ames Research Center	720
Dryden Flight Research Center	600
Glenn Research Center	3,895
Goddard Space Flight Center	540
Jet Propulsion Laboratory	3,010
Johnson Space Center	1,060
Kennedy Space Center	9,000
Langley Research Center	140
Marshall Space Flight Center	8,000
Michoud Assembly Facility	1,200
Stennis Space Center	4,800
Wallops Flight Facility	1,610
White Sands Test Flight Facility	4,300
Headquarters	2,125

PROGRAM DESCRIPTION:
The Program provides for environmental activities necessary for compliance with environmental requirements including environmental program initiatives. Proposed environmental activities for FY 2001 are identified below under "ENVIRONMENTAL ACTIVITIES COST ESTIMATE" title. The Program includes activities necessary for NASA to comply with environmental statutory and regulatory requirements and standards, orders, regulatory and cooperative agreements, and support of environmental program initiatives. The Program focuses our efforts in the principal areas of environmental compliance, remediation, conservation, pollution prevention and closures. Within this framework, compliance with environmental requirements is performed, while simultaneously remediating previously contaminated sites, performing environmental closures, and promoting the identification of pollution prevention and conservation activities. The resources authorized and appropriated pursuant to this Program may not be applied to other activities. Program activities include projects, studies, assessments, investigations, plans, designs, related engineering, program support, and sampling, monitoring, and operation of remedial treatment processes as part of the remediation and cleanup measures. These activities will be performed at NASA installations, NASA-owned industrial plants supporting NASA activities, and other current or former NASA sites where NASA operations have contributed to environmental problems and NASA is obligated to contribute to cleanup costs. In addition, these resources will be used to provide for regulatory agency oversight costs, to acquire land if necessary to implement environmental compliance and restoration measures, and to perform studies, assessments and other activities in support of functional leadership initiatives related to the environmental program.

PROGRAM JUSTIFICATION:

The Program represents this year's request on a phased approach in relation to the total Agency requirements for environmental remediation measures that must be implemented within the next several years, as well as for needed requirements for other environmental compliance measures. The Program includes activities necessary for compliance with environmental statutory and regulatory requirements and standards, orders, regulatory and cooperative agreements, and support of environmental program initiatives. Based on relative urgency and potential health hazards and safety, these activities are the highest priority requirements currently planned for accomplishment in FY 2001. Deferral of these necessary compliance and remedial measures would preclude NASA from complying with environmental requirements and regulatory agreements, and jeopardize NASA operations. As studies, assessments, investigations, plans, regulatory approvals, and designs progress and as new discoveries or regulatory requirements change, it is expected that priorities may change and revisions to these activities may be necessary.

The broad environmental categories summarizing the efforts proposed to be undertaken with the identified estimated costs are listed below. Remediation activities include one or more phases of a site cleanup program from site identification to final closeout, including but not limited to site assessments, site investigations, interim cleanup actions, testing and evaluation, remedial treatment systems and processes, monitoring, and other activities associated with CERCLA/RCRA cleanup requirements.

a. Environmental Remediation Activities and Initiatives --- Remediation (e.g. CERCLA, RCRA) .....$ 34,510
b. Other Environmental Compliance Requirements and Initiatives ---
   Compliance, Restoration, Prevention, Closures (e.g. CAA, CWA, RCRA, ESA, AEA, PPA) .....$ 6,490

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
RCRA = Resource Conservation and Recovery Act
CAA = Clean Air Act
CWA = Clean Water Act
ESA = Endangered Species Act
AEA = Atomic Energy Act
PPA = Pollution Prevention Act

ENVIRONMENTAL ACTIVITIES COST ESTIMATE (Thousands of Dollars):
The activities that comprise this request are as listed below by location.

A. Ames Research Center (ARC)	250
1. Remediation of Area of Investigation 5 – (Solvents)	250
B. Dryden Flight Research Center (DFRF)	600
1. Remediation of Soil/Groundwater Contamination	600
C. Glenn Research Center (GRC)	3,340
1. Remediation Activities at Operable Unit, (PBS)	225
2. Remediation of Contaminated Areas	500
3. Sewer System Compliance Modifications, Various Locations	600
4. Plum Brook Reactor Decommissioning Planning Activities	2,015
D. Goddard Space Flight Center (GSFC)	200
1. Remediation of Landfills (4)	200
E. Johnson Space Center (JSC)	800
1. Environmental Assessment/ Cleanup, NIP, Downey	150
2. Remediation of Monitoring Well #2 Area	400
3. Closure of Oil/Water Treatment System, Ellington Field	250
F. Kennedy Space Center (KSC)	5,000
1. Remediation at Launch Complex 34 (CCAS) Site, Interim Action	700
2. Remediation at Hydrocarbon Burn Facility Site	1,000
3. Remediation at Wilsons Corner Site, Phase 2	200
4. Remediation at MLP Rehabilitation Site	1,000
5. Remediation at Crawler Park (East) Site	400
6. Remediation at Fuel Storage Area 1 (CCAS) Site, Interim Action	700
7. Restoration of Wetlands and Scrub Habitat	300
8. Various Interim Measures, Various Locations (KSC and CCAS)	700

G. Marshall Space Flight Center (MSFC)	6,900
1. CERCLA Investigation and Cleanup	5,700
2. RCRA Investigation and Cleanup, Santa Susana Field Laboratory	500
3. Sewer System Rerouting and Compliance Modifications, Phase 2	700
H. Michoud Assembly Facility (MAF)	1,150
1. Remediation Activities, Various Locations	1,150
I. Stennis Space Center (SSC)	4,100
1. Remediation Activities at Various Sites, Areas II & I	4,100
J. Wallops Flight Facility (WFF)	1,300
1. Remediation of Contaminated Sites (4)	1,300
K. White Sands Test Facility (WSTF)	4,300
1. Groundwater Contamination Assessment and Remediation	4,300
L. Studies, Assessments, and Investigations; Plans; Designs; Sampling, Monitoring and Operation of Remedial Treatment Systems; Related Engineering and Program Support, Various Locations	13,060
Total Environmental Compliance and Restoration Program	41,000

INSPECTOR GENERAL

FISCAL YEAR 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF INSPECTOR GENERAL

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET
		(Thousands of Dollars)	
Personnel & related costs	17,826	19,100	20,100
Travel	996	600	1,200
Operation of installation	790	300	700
Total	19,612	20,000	22,000
Distribution of Program Amount by Installation			
Headquarters	19,612	20,000	22,000
Total	19,612	20,000	22,000

INTRODUCTION

The NASA Office of Inspector General (OIG) budget request of $22.0 million for FY 2001 fully funds 213 Full-Time Equivalents (FTEs). We currently are staffed at 202 FTE and, when current hiring actions are completed in FY 2000, we will be staffed at 209 FTE. The budget request of $22.0 allows the OIG to fully fund the 213 FTE staffing level including the projected COLA's. It allows the recruitment of three additional Computer Crimes Division (CCD) personnel to perform forensic evidence retrieval and advanced programming. The CCD staff is needed to evaluate the serious national and international penetrations targeted at NASA's systems, including mission critical systems. The NASA OIG has been in the forefront of responding to the priority Presidential Decision Directive (PDD) 63 to protect critical cyber infrastructure. Our actual budget request and FTE requirements will allow the OIG to perform its legislated mission as well as respond to Congressional requests, including Government Performance Results Act reviews.

At the requested level, the OIG will: (1) provide assistance and work cooperatively with Agency management as it carries out NASA's programs and operations; (2) maintain a balanced audit program, including providing technical assistance and oversight of the audit of the Agency's financial statements as required by the Chief Financial Officers (CFO) Act; (3) concentrate investigative resources on procurement fraud and network, computer, and telecommunications crime matters including emphasis on prevention initiatives; (4) work cooperatively with management by conducting inspections, assessments and reviews of issues identified by the OIG and those of concern to Agency management and Congress; and (5) deploy audit staff to timely provide feedback on NASA's re-engineering and streamlining initiatives. This budget level recognizes the fiscal constraints facing the Agency and the need for the OIG to provide quality products and services that are timely and meet our customers' needs. The Inspector General also continues streamlining activities to increase the mission capability of the OIG staff. Initiatives include continued conversion, whenever possible, of administrative overhead positions to program assistants and analysts responsible for assisting on direct mission activities of the audit, investigative, and inspection missions; and matrixing existing personnel and management analyst positions to support direct mission activities. In addition, the OIG continues to streamline and simplify communications and reporting channels, and improve computer and telecommunications capacities to further increase staff capabilities.

The OIG's missions include conducting independent audits, investigations, and reviews of NASA's programs and operations while working as cooperatively as feasible with NASA's management and program managers. Audits will be prioritized and selected to evaluate programmatic, operational and financial management concerns; information technology systems, security, and operations; and internal control vulnerabilities. The investigations program, with its computer and network crimes capability, will continue to place greater emphasis on the investigation of computer intrusions and frauds in which the computer was used as an instrument of the crime. The investigation's program also will continue focusing on complex procurement and other criminal matters including fraud against the Government by contractor and Government employees, product substitution, and other procurement irregularities. Inspections, assessments, and reviews will be conducted which support management's interests and concerns in achieving NASA's programmatic objectives more efficiently and effectively; issues of Congressional concern; matters of high Agency vulnerability; and administrative inquiries related to unethical and improper conduct, waste and mismanagement.

OBJECTIVES AND STATUS

This request represents the minimum OIG resources (FTEs) needed at NASA Headquarters and field offices to fulfill the OIG mission. Recognizing that every identified audit, investigation, inspection, assessment, and other workload review significantly taxes the available resources, continuous adjustments of priorities will be necessary to ensure a balanced coverage of NASA's programs and operations is maintained; all critical and sensitive matters are promptly evaluated and investigated; and all OIG customers receive timely, accurate, and complete responses.

The OIG uses a formal process to identify, review, prioritize, and select the audits, inspections, evaluations, and reviews to be performed. The OIG assignments are derived from: (1) monitoring NASA's evolving initiatives in downsizing, re-engineering, commercialization, and privatization to determine opportunities for efficiencies and vulnerabilities; (2) selecting audits and reviews

using a structured approach encompassing NASA's programs and operations, and an external universe comprised of NASA's prime contractors, their subcontractors, and grantees; and (3) addressing issues required by laws and internal regulations. The audits and reviews identified from these sources are prioritized, balanced against available resources, and published in the annual OIG work plan. The OIG will continue its NASA-wide program-oriented reviews to obtain greater visibility and awareness of issues related to NASA's major programs and initiatives.

Agency vulnerabilities are determined by taking into consideration the following: (1) whether program and project objectives are accomplished in the most cost effective manner and comply with safety and mission quality initiatives; (2) whether management's actions are sufficient to correct internal control weaknesses reported under the Federal Manager's Financial Integrity Act (FMFIA); (3) whether NASA's annual expenditure on information technology is providing expected programmatic and financial information needed to make sound decisions (NASA is one of the top ranked civilian agencies in information technology spending); (4) whether improvements are implemented in financial management systems, practices, controls, and information; (5) whether the audit follow-up system is effective in enabling management to maintain the status of corrective actions; and (6) whether Agency-wide corrective actions addressing environmental concerns are adequate. Each of the identified vulnerabilities are evaluated, prioritized, and included in our plans for further action.

Further, Agency program and project changes, growth, delays, and terminations increase the need for OIG oversight of contractor/subcontractor/grantee cost, schedule, and performance effectiveness. During and beyond FY 2000, the Agency will potentially be faced with an array of problems resulting from computer systems not being able to successfully transition to the "00" calendar year. It has been estimated that the Year 2000 problems will extend beyond the first decade of the 21st century. Moreover, the Agency is developing a number of technology programs that will be reaching critical milestones in FY 2000 and beyond that have not yet received audit coverage. NASA's continued reliance on contractors and grantees (about 85 percent of the Agency's total obligations are for procurement) will require increasing direct OIG involvement and oversight of Defense Contract Audit Agency (DCAA) and Health and Human Services (HHS) OIG audits of NASA contractors and grantees to ensure effective contract and grant execution and administration. During FY 1999, NASA was billed about $43 million for contract audit services.

During FY 2001, the OIG will continue to focus attention and provide support to program managers on issues relating to: Earth Science, Communications, Human Exploration and Development of Space, Space Technology, Information Technology, Aeronautics, and Space Transportation. The functional areas we will evaluate include Procurement and Contract Administration, Technology Transfer, Financial Management, Information Resources Management, Information Systems and Communications Security, Environmental issues, and Facilities and Equipment. The OIG's Information Technology Program and Information Assurance audit groups will continue to focus on the security and integrity of NASA's major information systems and operations. Financial management's significance increased dramatically with the passage of the CFO Act. Pursuant to the Inspector General Act and Title 31, we have selected independent certified public accountants to render an opinion on the Agency's annual financial statements, its internal control structure, and its compliance with laws and regulations. Our financial audits will concentrate on accounting controls, information systems, and required performance measurements.

The OIG investigative workload continues to squeeze the availability of investigative resources, especially in the area of cyber network intrusions. The minimal FY 2001 investigative staffing level will require the OIG to effectively manage the complex workload of investigative criminal and civil fraud matters. The establishment of the Computer Crimes Division allows the OIG to investigate unauthorized intrusions into and compromises of NASA and contractor network systems, as well as assessing vulnerability to information terrorism. The increase in the network crimes investigative caseload rose significantly in FY 2000 and will continue exponential growth in FY 2001. We prioritize our resources to focus on the international and national penetrations and intrusions of NASA's networks and systems, and economic espionage as well as other serious intrusions, which cause losses of communications services involving hundreds of thousands of dollars per intrusion. We are finding more and more intrusions that use NASA funded networks to further other criminal enterprises including the compromise of advanced technologies and industrial espionage. The number of complex procurement fraud cases also remains high. These kinds of cases take longer to resolve and are resource intensive, thereby limiting our flexibility to expand the program. We are working with management to help us address all substantive allegations received, to refer more routine administrative matters to them for their resolution, and request that they keep the OIG advised of the action taken. We are also referring more serious administrative matters to the OIG Inspections and Assessments (I&A) staff for review. By referring matters to Agency managers or our I&A staff to resolve, we can reserve our criminal investigative resources to address the more serious fraud allegations.

In summary, the OIG will collaborate with Agency management to address issues of joint concern to improve scope, timeliness, and thoroughness of its oversight of NASA programs and operations; identify preventive measures; and enhance our capabilities to assist NASA management to efficiently and effectively achieve program and project goals and objectives.

SCHEDULE & OUTPUTS

WORKLOAD	FY 1999	FY 2000	FY 2001
Office Staff Ceiling			
Full-Time Equivalents	191	210	213
Investigations			
Cases pending beginning of year	288	312	338
Opened during year	170	187	206
Closed during year	146	161	177
Cases pending end of year	312	338	367
Audits			
Audits pending beginning of year	33	36	40
Opened during year	73*	64	62
Closed during year	70	60	65
Audits pending end of year	36	40	37
Inspections & Assessments (IA) and Partnerships & Alliances (PA)			
IA Administrative Investigations pending beginning of year	87	142	132
Opened during year	156	160	165
Closed during year	101	170	185
IA Administrative Investigations pending end of year	142	132	112
IA and PA Reviews pending beginning of year	5	14	19
Opened during year	20	25	25
Closed during year	11	20	25
IA and PA Reviews pending end of year	14	19	19

*Emphasis on Agency-wide performance audits

BASIS OF FY 2001 FUNDING REQUIREMENT

PERSONNEL AND RELATED COSTS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Compensation and Benefits	**17,198**	**18,875**	**19,440**
Compensation	14,068	15,520	15,910
(Full-time permanent)	14,024	15,520	15,860
(Other than full-time permanent)	34	0	0
(Overtime & other compensation)	10	0	0
Benefits	3,130	3,355	3,530
Supporting Costs	**628**	**225**	**660**
Transfer of personnel	407	180	440
Personnel training	221	45	220
OPM Services	0	0	0
Total	**17,826**	**19,100**	**20,100**

FULL-TIME EQUIVALENTS

Full-time permanent	191	210	213
Other controlled FTEs	0	0	0
Total	191	210	213

These estimates provide the resources required for full staffing of NASA OIG's Information Technology Audit and Computer Crimes Divisions.

TRAVEL

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Travel	996	600	1,200

Travel funding is required to carry out audit, investigation, inspection and assessment, partnerships and alliances, and management duties. Our budget allows for increases in per diem, airline costs, and workloads. We anticipate increased travel by our information technology audit and computer crimes teams. Also, in order to respond to NASA's changing priorities (and implementation of its centers of excellence and commercialization efforts), increased travel funds will be required to deploy staff located at field offices remote from the site where audit and investigation activities occur.

OPERATION OF INSTALLATION

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Technical Services	379	105	350
Management and Operations	411	195	350
Total	790	300	700

Operation of Installation provides a broad range of services and equipment in support of the Inspector General's activities.

The Technical Services estimate provides for all equipment, including purchase, maintenance, programming and operations of unique automated data processing (ADP) equipment. NASA provides common services items such as office space, communications, supplies, and printing and reproduction at no charge to the Office of Inspector General. The funding for Technical Services will cover the cost of providing unique ADP upgrades, and replacement of unique equipment that has become outdated or unserviceable. As funding permits, in FY 2001 we will continue to improve our PC-based wide-area network and management information system.

The Management and Operations category includes miscellaneous expenses within the Office of Inspector General, i.e., GSA cars, the Inspector General's confidential fund, miscellaneous contracts, and supplies not provided by NASA.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, as amended, [$20,800,000] *$20,000,000. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2000.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHANGES FROM FY 2000 BUDGET ESTIMATE TO FY 2000 CURRENT ESTIMATE

	NASA FY 2000 Request	Delta	12/23/99 Initial Op Plan	*P.L. 106-113 Rescission & Add'l Changes	Current FY 2000
			(Millions of Dollars)		
HUMAN SPACE FLIGHT	**5,638.0**	**-127.1**	**5,510.9**	**-43.200**	**5,467.700**
Space Station	2,482.7	-148.1	2,334.6	-11.500	2,323.100
Space Shuttle	2,986.2	25.0	3,011.2	-31.700	2,979.500
Payload Utilization & Operations	169.1	-4.0	165.1		165.100
Science, Aero & Technology	**5,424.7**	**182.0**	**5,606.7**	**-25.805**	**5,580.895**
Space Science	2,196.6	1.5	2,198.1	-5.315	2,192.785
Life & Microgravity Sciences & Applications	256.2	20.3	276.5	-1.779	274.721
Earth Science	1,459.1	-12.6	1,446.5	-3.075	1,443.425
Aero-Space Technology	1006.5	131.5	1138.0	-13.146	1,124.854
Mission Communication Services	406.3	0.0	406.3		406.300
Academic Programs	100.0	41.3	141.3	-2.490	138.810
Mission Support	**2,494.9**	**20.2**	**2,515.1**	**17.124**	**2,532.224**
Safety, Mission Assur, Eng & Adv Concepts	43.0		43.0		43.000
Space Communication Services	89.7		89.7		89.700
Total Research & Program Management	2,181.2	19.3	2,200.5	17.124	2,217.624
Construction Of Facilities	181.0	0.9	181.9		181.900
Inspector General	**20.8**	**-0.8**	**20.0**		**20.000**
NASA TOTAL	**13,578.4**	**74.3**	**13,652.7**	**-51.881**	**13,600.819**

*reflects both 0.38% rescission and $20.2M tranfer from the Human Space Flight account to the Mission Support account.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHANGES FROM FY 2000 BUDGET ESTIMATE TO FY 2000 CURRENT ESTIMATE

	NASA FY 2000 Request	Delta	12/23/99 Initial Op Plan	*P.L. 106-113 Rescission & Add'l Changes	Current FY 2000
HUMAN SPACE FLIGHT	**5,638.0**	**-127.1**	**5,510.9**	**-43.200**	**5,467.700**
Space Station	**2,482.7**	**-148.1**	**2,334.6**	**-11.500**	**2,323.100**
Vehicle	890.1		890.1		890.100
Operations Capability	850.2	-54.1	796.1	-32.500	763.600
Research	394.4		394.4		394.400
Russian Program Assurance	200.0		200.0		200.000
Crew Return Vehicle	148.0	-94.0	54.0	21.000	75.000
Space Shuttle	**2,986.2**	**25.0**	**3,011.2**	**-31.700**	**2,979.500**
Shuttle Operations	2,547.4	-25.0	2,522.4	-31.700	2,490.700
Orbiter and Integration	709.4		709.4	-10.600	698.800
Propulsion	1,133.2	-70.6	1,062.6	-9.500	1,053.100
Mission and Launch Operations	704.8	45.6	750.4	-11.600	738.800
Safety/Performance Upgrades	438.8	50.0	488.8		488.800
Orbiter Improvements	196.6	-12.9	183.7		183.700
Propulsion Upgrades	118.7	62.9	181.6		181.600
Flight Operations & Launch Site Equipment	112.5		112.5		112.500
Construction of Facilities	11.0		11.0		11.000
Payload Utilization & Operations	**169.1**	**-4.0**	**165.1**		**165.100**
Payload Processing and Support	49.3		49.3		49.300
ELV Mission Support	28.6	2.0	30.6		30.600
Advanced Projects (X-38)	6.0	-6.0	0.0		0.000
Engineering and Technical Base	85.2		85.2		85.200

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CHANGES FROM FY 2000 BUDGET ESTIMATE TO FY 2000 CURRENT ESTIMATE

	NASA FY 2000 Request	Delta	12/23/99 Initial Op Plan	*P.L. 106-113 Rescission & Add'l Changes	Current FY 2000
Science, Aero & Technology	**5,424.7**	**182.0**	**5,606.7**	**-25.805**	**5,580.895**
Space Science	**2,196.6**	**1.5**	**2,198.1**	**-5.315**	**2,192.785**
Chandra Development	0.0	4.1	4.1		4.100
GP-B	40.5	9.4	49.9		49.900
HST Development	140.4	19.7	160.1		160.100
SOFIA	45.1	-6.1	39.0		39.000
SIRTF	125.0	-1.6	123.4		123.400
TIMED Development	16.0	11.5	27.5		27.500
Payload & Instrument Development	10.0	3.6	13.6		13.600
Explorers	151.0	-28.7	122.3		122.300
Mars Surveyor	250.7	-2.3	248.4		248.400
Discovery	180.5	-25.7	154.8		154.800
Mission Operations	85.3	-9.9	75.4		75.400
Supporting Research & Technology	1,152.1	27.5	1,179.6	-5.315	1,174.285
Life & Microgravity Sciences & Applications	**256.2**	**20.3**	**276.5**	**-1.779**	**274.721**
Advanced Human Support Technology	29.2	1.1	30.3	-0.085	30.215
Biomedical Research & Countermeasures	53.0	4.7	57.7	-0.508	57.192
Gravitational Biology & Ecology	38.6	-0.4	38.2		38.200
Microgravity Research	111.4	-2.6	108.8		108.800
Space Products Development	14.4		14.4		14.400
Space Medicine	7.1	0.2	7.3		7.300
Occupational Health	1.1	0.3	1.4		1.400
Mission Integration	1.4	17.0	18.4	-1.186	17.214
Earth Science	**1,459.1**	**-12.6**	**1,446.5**	**-3.075**	**1,443.425**
Earth Observing System	663.2	-87.7	575.5	-0.085	575.415
EOSDIS	231.5	31.0	262.5	-0.594	261.906
Earth Probes	138.2	19.2	157.4		157.400
Applied Research and Data Analysis	420.2	18.7	438.9	-2.396	436.504
GLOBE	5.0		5.0		5.000
SRTM	0.0	6.2	6.2		6.200
CoF	1.0		1.0		1.000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CHANGES FROM FY 2000 BUDGET ESTIMATE TO FY 2000 CURRENT ESTIMATE

	NASA FY 2000 Request	Delta	12/23/99 Initial Op Plan	*P.L. 106-113 Rescission & Add'l Changes	Current FY 2000
Aero-Space Technology	**1006.5**	**131.5**	**1138.0**	**-13.146**	**1,124.854**
Research and Technology Base	511.4	80.3	591.7	-10.080	581.620
Focused Programs	362.6	43.0	405.6	-2.371	403.229
Aviation Systems Capacity	60.0	3.2	63.2	-0.271	62.929
Aviation Safety	60.0	4.8	64.8	-0.406	64.394
High Performance Computing & Communications	24.2	0.0	24.2		24.200
Ultra Efficient Engine Technology	50.0	20.0	70.0	-1.694	68.306
Future-X Flight Demonstrations – Pathfinders	31.3	0.0	31.3		31.300
X-34	25.5	15.0	40.5		40.500
X-33	111.6	0.0	111.6		111.600
Commercial Technology Program	132.5	8.2	140.7	-0.695	140.005
Mission Communication Services	**406.3**	**0.0**	**406.3**		**406.300**
Ground Network	228.8	-66.8	162.0		162.000
Mission Control & Data Systems	150.5	83.3	233.8		233.800
Space Network Customer Services	27.0	-16.5	10.5		10.500
Academic Programs	**100.0**	**41.3**	**141.3**	**-2.490**	**138.810**
Education Programs	54.1	32.7	86.8	-1.761	85.039
Minority University Research & Education	45.9	8.6	54.5	-0.729	53.771
Mission Support	**2,494.9**	**20.2**	**2,515.1**	**17.124**	**2,532.224**
Safety, Mission Assur, Eng & Adv Concepts	**43.0**		**43.0**		**43.000**
Space Communication Services	**89.7**		**89.7**		**89.700**
Space Network	37.8	-1.7	36.1		36.100
Telecommunications	51.9	1.7	53.6		53.600
Total Research & Program Management	**2,181.2**	**19.3**	**2,200.5**	**17.124**	**2,217.624**
Construction Of Facilities	**181.0**	**0.9**	**181.9**		**181.900**
Inspector General	**20.8**	**-0.8**	**20.0**		**20.000**
NASA TOTAL	**13,578.4**	**74.3**	**13,652.7**	**-51.881**	**13,600.819**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHANGES FROM FY 2000 BUDGET ESTIMATE TO FY 2000 CURRENT ESTIMATE

CHANGES SINCE THE 12/23/99 OPERATING PLAN

Rescission
Per Public Law 106-113, NASA's FY 1999 appropriation was reduced 0.38 percent, or $51,881,000. This rescission was accommodated by reducing Human Space Flight $23,000,000; reducing Science, Aeronautics and Technology $25,805,000; and reducing Mission Support $3,076,000.

Space Station
The FY 2000 estimate is reduced $11,500,000 to accommodate a portion of the Human Space Flight rescission (above). Additionally, $21,000,000 is reallocated from Operations Capability to Crew Return Vehicle (CRV) in order to maintain the Phase 1 development for the CRV.

Space Shuttle
The FY 2000 estimate is reduced $11,500,000 to accomondate a portion of the Human Space Flight recission (above). Additionally, $20,200,000 is transferred from Space Shuttle Oprations to Research and Program Management (R&PM) in the Mission Support approproation in order to fund additional hiring of personnel in critical skill areas at Human Space Flight centers (JSC, MSFC, KSC, and SSC), as described below.

Transfer Authority
The President's FY 2001 budget request proposes the following transfer, that is found in the supplementals appendix:

> "The last proviso under this heading in P. L. 106-74 is repealed,
> provided that $ 20,200,000 shall be transferred to "Mission support".

This request repeals the $40,000,000 that was intended for an additional Space Shuttle research flight in favor of funding higher priority safety investments that will ensure the continued safe operation of the Space Shuttle. The amount of $20,200,000 is transferred from Space Shuttle Oprations to Research and Program Management (R&PM) in the Mission Support approproation in order to fund additional hiring of personnel in critical skill areas at Human Space Flight centers (JSC, MSFC, KSC, and SSC), and $19,800,000 is applied to high priority safety upgrades in the Space Shuttle program that will be fully in place in the Shuttle fleet by 2005.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 2001 BUDGET ESTIMATES
FULL-COST MANAGEMENT

During 1995, the National Aeronautics and Space Administration (NASA) began a multi-year initiative to introduce full-cost practices into NASA. Full-cost practices involve new management, budgeting, and accounting changes. The changes are designed to provide new, detailed, complete cost information and thereby support improved (more cost effective) mission performance and related administrative improvements. Full-cost practices (also for brevity collectively referred to as full-cost management) integrate new cost accounting information on all aspects of NASA's activities. Managers will ensure that all activities cost-effectively support NASA missions by using this information. Full-cost budget information will highlight the full cost (including support costs) of each NASA project and thereby support more complete, "full" disclosure of NASA's activities, clearer linkage between resource inputs and outputs/outcomes, and greater accountability regarding NASA's use of taxpayer resources.

NASA's full cost practices are designed to provide useful, detailed cost information for internal management and appropriate cost information for external oversight. Such information is expected to result in improved decisions and more cost effective mission performance. NASA's practices also comply with related Federal legislation, such as the 1990 Chief Financial Officers (CFO) Act, the 1993 Government Performance and Results Act (GPRA) and the 1996 Federal Financial Management Improvement Act.

As NASA formulates its FY 2002 budget request, the decision process will be conducted using certain, key "full cost" information from its programs. Concurrently, NASA will be working with the Administration and the Congress to develop the new appropriation structure and the necessary transition mechanisms from the present account structure. Particular attention will be paid to the need for flexibility on the linking of civil service and supporting costs among programs and projects in a research and development environment. Timely conclusion of these precursor discussions is critical to the future full implementation of a full cost appropriation budget presentation for FY 2002, and the execution of the enacted appropriation. NASA will also be closely monitoring the progress being made on the installation of a new, NASA-wide standard, integrated financial management system. Due to difficulties encountered during the test phase of the system software, there is currently significant uncertainty regarding the timing of availability of the new software. The capabilities of the new system for budget execution and accounting are essential to meeting the internal control standards required to execute key elements of the FY 2002 appropriation in a full-cost environment.

NASA has tested full-cost concepts across the agency and determined the feasibility of implementation and anticipated benefits, conducting a Full Cost Simulation across the agency in conjunction with the initial FY 2000 budget request, and conducting full cost data collection in the formulation of the FY 2001 budget. These exercises identified the need for additional process improvements and clarifications in the draft guidance documents. Provided below is a summary of the status, purpose and background of NASA's full-cost initiative. Also highlighted are key legislative authorities that will support the timely, effective implementation of full cost practices in NASA.

Supplemental information is available through the NASA CFO Internet site at http://ifmp.nasa.gov/codeb/initiatives/standard.htm

Purpose

The purpose of the full-cost initiative is to develop and implement full-cost accounting, budgeting, and management practices in NASA. The purpose of implementing such full-cost management is to support cost-effective mission performance through timely, reliable financial information and practices.

Simply stated, full-cost management can be expected to help to ensure optimum mission performance with the minimum essential resources. In that regard, full-cost practices are expected to:

- Support more cost effective mission performance
- Motivate managers to operate efficiently
- Support economic decisions for appropriate resource allocations
- Help justify NASA's budget on a program/project basis
- Support analysis and decision-making regarding full project costs
- Support analysis and decision-making regarding NASA services provided to others (reimbursable activities)
- Support bench-marking of NASA service activities with other similar services
- Strengthen accountability regarding NASA's effective and efficient use of tax dollars to achieve NASA missions.

NASA is pursuing full-cost management at this time because NASA requires related cost information to more effectively manage within the current and anticipated future environment. This environment includes constrained budgets and increased expectations regarding oversight and accountability.

Background

NASA's full-cost management initiative began in 1995 in response to guidance from several NASA and Federal authorities. While the initiative was undertaken in direct response to a specific management initiative of the NASA Administrator, the initiative also responded to guidance indicated in NASA's 1995 Zero Base Review and mandates in several key Federal financial and performance laws and related standards.

In early 1995, the NASA Administrator requested key cost information for NASA and for each NASA Center. In pursuing the Administrator's request, the NASA Chief Financial Officer confirmed that NASA's nonstandard, decentralized accounting systems did not regularly capture all required cost information in a timely, standard, useful manner. Shortly thereafter, in April 1995, NASA initiated its full-cost effort.

During 1995, NASA also completed a Zero Base Review that involved a comprehensive analysis related to streamlining NASA activities. This review also highlighted several weaknesses involving the inconsistent recognition of the total costs of certain NASA activities and the related analytical complications of inconsistent cost information. The Zero Base Review team indicated that NASA should improve cost information and pursue full-cost management.

During 1995, Federal accounting standards-setting organizations also completed key initiatives related to cost accounting. These organizations approved a new managerial cost accounting standard, including a specific standard on full-cost accounting. This standard (and other Federal accounting standards) evolved from recent Federal financial and performance legislation.

During the past few years, financial and performance legislation highlighted key Federal cost accounting and reporting requirements. This legislation included the CFO Act of 1990 and the Government Performance and Results Act of 1993. In addition, more recently the Federal Financial Management Improvement Act of 1996 highlighted and specified other key full-cost accounting requirements. The 1996 Act stated the following.

> "The purposes of this Act are to...require Federal financial systems to support full disclosure of Federal financial data, including the full costs of Federal programs and activities, to the citizens, the Congress, and President, and agency management, so that programs and activities can be considered based on their full costs and merits..."
>
> "Each agency shall implement and maintain management systems that comply substantially with Federal financial management systems requirements, applicable Federal accounting standards, and the United States Government's Standard General Ledger at the transaction level."

NASA's full-cost initiative evolved from these internal NASA initiatives, as well as, several related Government-wide initiatives.

During 1995, NASA developed key full-cost concepts and specified related cost information requirements as part of an ongoing Integrated Financial Management system initiative. NASA's full-cost concepts were approved by NASA management in early 1996.

NASA's full-cost concept integrates several fundamental improvements. The planned improvements include: accounting for all NASA costs as direct costs, service costs, or general and administrative (G&A) costs; budgeting for all appropriate program/project/initiative ("project") costs; and managing such "projects" from a full-cost perspective. Direct costs are costs that can be obviously and/or physically linked to a particular project. Service costs are costs that cannot be initially, readily and/or immediately linked to a cost objective, but subsequently can be traced either to a project or to G&A activities (optimally based on service consumption). G&A costs are support costs that either cannot be to a specific project or where the expense of doing so would be uneconomical. Such costs are typically allocated to cost objectives (or projects) by using allocation methods, which meet the tests of reasonableness and consistency.

During 1996, NASA tested full-cost concepts at four NASA prototype test locations (three Centers and Headquarters). The prototype test indicated that NASA could benefit significantly from the introduction of full-cost practices throughout the agency.

During 1997, NASA completed an agency-wide test of full-cost practices that confirmed its earlier observations that NASA could benefit significantly from the implementation on full-cost practices. The 1997 test also confirmed that NASA needed a new integrated financial system to cost effectively and efficiently support all elements of full cost budgeting and accounting. Cost finding techniques that were used to develop full cost accounting estimates after-the-fact proved to be extremely resource-intensive and could not produce needed data in a timely fashion. Furthermore, the timely, efficient formulation of the budget in a full cost format also proved to be extremely resource-intensive and basically unworkable as an ongoing approach.

Status

During 1998, NASA continued testing and refining full-cost practices. A Full Cost Simulation was conducted across the agency utilizing an early version of the FY 2000 budget proposal. The major focus of this simulation was to determine how best to manage in the full cost environment, particularly in regard to service pools and G&A expense pools. Field Center and Headquarters results and issues were presented to a panel of Deputy Center Directors and Deputy Associate Administrators from throughout the agency, who made management recommendations that were integrated into the agency's Full Cost Implementation Guide.

This 1998 test also served as the first utilization of an early version of a valuable tool in terms of process efficiencies -- the Integrated Financial Management System (IFMS) budget formulation system. NASA used this new budget formulation system to develop and analyze budgetary requirements for the FY 2001 submission.

As an important step in implementing full cost practices, NASA developed the full cost of major programs/projects for FY 1998 and FY 1999, and included this information in its audited financial statements.

In late 1999, NASA reached a consensus that full cost practices should be implemented in an efficient and economical manner, as soon as possible. The basic implementation strategy is to phase key full cost practices into Center and Agency operations over the next few years. Centers were directed to initiate full cost activities with a focus on (1) direct labor cost distribution to projects and (2) G&A and service pool structure standardization in FY 2000. Centers are to capture all direct costs, including labor, by project, and report, on a phased basis, such full cost data to Center project managers. FY 2001 activities will be decided upon as NASA progresses on FY 2000 activities.

NASA Proposal for Optimization of Full-Cost Management

The strength and benefits of NASA's full cost practices are optimized by the integration and synergy of changes in each area (management, budgeting, and accounting). Full-cost accounting by itself, over time, would likely lead to gradual budget and management improvements. However, concurrent changes to full cost practices in the accounting, budgeting, and management areas can be expected to ensure that NASA optimizes improvements in each area, as soon as possible. To this end, NASA has decided to pursue key appropriation/budget structure changes as part of the full cost initiative. Furthermore, certain legislative provisions are being pursued to ensure that NASA achieves all of the key benefits of its full-cost practices, while NASA retains its long-standing ability to appropriately and efficiently assign/reassign its staff to achieve mission requirements.

NASA plans to work with OMB and Congress in 2000 in order to pursue legislative proposals to optimize the implementation of full cost practices. It is expected that discussions will focus on the agency's appropriation/operating plan/budget structure and the levels of Congressional control; and the resolution and utilization of unobligated and unexpired balances from the current Mission Support account into the other accounts, along with other operational matters.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

MULTI-YEAR APPROPRIATIONS
(IN MILLIONS OF REAL YEAR DOLLARS)

NASA is seeking multi-year appropriations for the following selected projects:

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
INTERNATIONAL SPACE STATION	**2114.5**	**1858.5**	**1452.5**	**1327.0**	**1275.0**

National Aeronautics and Space Administration

Major NASA Development Programs
Program Cost Estimates

This special section of the FY 2001 budget justifications provides information about major NASA programs that are either in the design and development phase or have not completed their initial operational phase. In several instances, information about programs which are not "major" but are of special interest has been included. The budgetary estimates are expressed in millions of dollars of *budget authority*.* Estimates of the FY 1999 and prior fiscal year budget authority are the "actual" amounts. The FY 2000 amounts are consistent with the FY 2000 initial operating plan. The amounts for FY 2001 and future fiscal years are expressed in "real year" economics, that is, they include an adjusting factor for the future inflation expected to be experienced. If the term "constant dollars" is used in the budget justifications, that phraseology indicates that the numbers do not include inflationary adjustments beyond the fiscal year referenced (e.g., "constant FY 1996 dollars").

The estimates provided below are intended to be comprehensive, including all related mission-unique costs, but there are limitations. The direct and indirect costs incurred by foreign governments or other federal agencies in support of these missions have not been included. The estimates of civil service costs have been included, but these estimates should be considered preliminary, and they will continue to be refined as the agency moves toward full cost accounting over the next several years.

* *Budget authority* is a term used to represent the amounts appropriated by the Congress in a given fiscal year; *budget authority* provides government agencies with the authority to obligate funds. The ensuing obligations, cost incurrence, and expenditures (outlays) can differ in timing from the fiscal year in which Congress provides the *budget authority* in an appropriations act.

X-33 Advanced Technology Demonstrator

The X-33 program will demonstrate, on the ground and on a flight demonstration vehicle, technologies and operations concepts that could reduce space transportation costs to one-tenth of their current level. The X-33 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level. The X-33 program Phase II selection was made in July 1996 based on specific programmatic, business planning, and technical criteria. NASA selected the Lockheed Martin Skunk Works to lead an industry team to develop and flight test the X-33.

The X-33 is an integrated technology effort to flight-demonstrate key Single Stage To Orbit (SSTO) technologies, and deliver advancements in: 1) ground and flight operations techniques that will substantially reduce operations costs for an RLV; 2) lighter, reusable cryogenic tanks; 3) lightweight, low-cost composite structures; 4) advanced Thermal Protection Systems to reduce maintenance; 5) propulsion and vehicle integration; and, 6) application of New Millennium microelectronics for vastly improved reliability and vehicle health management. X-33 will combine its results with the successes of the DC-XA, X-34 and complementary ground technology advances to reduce the technical risk of full-scale development of an operational RLV. The X-33 test vehicle will fly 13-15 times the speed of sound and will test the boundaries of current technology.

NASA is utilizing an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. As a result of industry's leadership of the program, Government participants are acting as partners and subcontractors, performing only those tasks for which they offer the most effective means to accomplish the program's goals. The Government participants report costs and manpower to the industry team leader as would any other subcontractor. Every NASA center except the Goddard Space Flight Center has a negotiated role on the X-33 program. The Industry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs and increased management efficiency

The X-33 program also funded refurbishment of rocket engine test stands at Stennis in FY 1997 ($2.3 million) and FY 1998 ($3.7 million) to enable testing of X-33 development and flight engines, as well as other future advanced space transportation engines. Civil Service estimates below are for the X-33 cooperative agreement only.

A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
COOPERATIVE AND TASK AGREEMENTS	560.7	239.1	111.6							911.4
OTHER X-33 ACTIVITIES	269.3	38.2								307.5
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M	830.0	277.3	111.6							1218.9
(ESTIMATED CIVIL SERVICE FTEs)	(739)	(280)	(161)	(22)	(8)	(8)	(8)	(7)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M	59.2	21.4	13.8	2.1	0.8	0.9	0.9	0.8		

Alternate Turbopump Development

Funding to begin development of an alternate design for the two turbopumps driving the Space Shuttle's Main Engine was initiated in FY 1987. The development of a new high-pressure oxygen turbopump and hydrogen fuel turbopump was undertaken to improve the safety, reliability, producibility, and maintainability of the current turbopumps. After an initial period of design and development, problems experienced in early development testing and accompanying increased costs resulted in suspension of the fuel turbopump's development, while development activities concentrated on the oxygen turbopump. Although further development problems were encountered with the oxygen turbopump, their successful resolution led to Congress agreeing in Spring 1994 to resumption of the fuel turbopump's development. The first flight of the oxygen turbopump occurred in 1995, and the initial flight of the fuel pump is currently planned for late 2000, rescheduled from late 1997 due to development problems. The budgetary estimate of $965.8 million includes not only the funding required for the design, development, and extensive testing of these two types of turbopumps, but also the funding needed to produce the flight turbopumps for installation into the main engines for the four-orbiter fleet.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT	697.2	34.8	21.3	2.9	1.0					757.2
IMPLEMENTATION	143.3	22.1	20.0	18.8	4.4					208.6
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	840.5	56.9	41.3	21.7	5.4					965.8
(ESTIMATED CIVIL SERVICE FTEs)	(539)	(22)	(15)	(7)	(2)					
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	30.0	1.9	1.3	0.6	0.2					

Super Lightweight Tank

The objective of the Super LightWeight Tank (SLWT) is to provide the Space Shuttle with 7,500 pounds of additional performance of payload capability. The weight reduction objective was achieved by selectively substituting high-strength, low-density, aluminum-lithium alloys, redesigning certain structural components, and reducing thermal protection thickness. The new SLWT physically and functionally replaced the existing External Tank (ET) with no launch processing impacts and without detriment to the other Shuttle system elements. NASA was given congressional approval to proceed in January 1994. The External Tank Project Office at the Marshall Space Flight Center in Alabama manages the SLWT, and Lockheed Martin is the ET prime contractor. The first flight of the SLWT (STS-91) was on June 2, 1998. The aluminum-lithium material is a specialty metal produced to rigorous specifications and accordingly costs more than the aluminum used at present. The development cost estimate is slightly higher than the FY 1999 estimate, as an additional $0.9M in residual development work was required in FY 1999 and FY 1999.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT COST	126.7	1.1	0.5							128.3
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	126.7	1.1	0.5							128.3
(ESTIMATED CIVIL SERVICE FTEs)	(231)									
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	17.1									

Checkout and Launch Control System (CLCS)

A new Checkout and Launch Control System (CLCS) was approved for development at KSC in FY 1997. The CLCS will upgrade the Shuttle launch control room systems with state-of-the-art commercial equipment and software in a phased manner to allow the existing flight schedule to be maintained. The CLCS will reduce operations and maintenance costs associated with the launch control room by as much as 50%, and will provide the building blocks to support future vehicle control system requirements. The Juno and Redstone phases were delivered in FY 1997. In these phases, the initial integration platform was defined, the engineering platform installed and the interface with the math models was established. The Thor delivery was completed in FY 1998. During this phase, initial ground databus interfaces were established and the system software was ported to the production platforms. The Atlas delivery in FY 1999 provided support for the Orbiter Processing Facility were developed, the final applications for the Hypergolic Maintenance Facility, the math model validation, an interface to the Shuttle Avionics Integration Lab (SAIL), and hardware testing for SAIL. The Titan delivery will provide support for completion of development and the start of validation testing for application software used for Shuttle Orbiter power-up testing. The Scout phase of CLCS is planned to support operational use in the Orbiter Processing Facility and development of Pad and launch-related application software. The Delta and Saturn phases include completion of all launch application development, completion of software certification and validation, and a complete integrated flow demonstration. Since the FY 1999 Budget, software independent validation and verification (IV&V) performed by Ames Research Center was also added to this project. By the end of FY 2002, Operations Control Room-1 will be fully operational, followed by certification. The first Shuttle launch using the CLCS is scheduled for FY 2002 with full implementation to be completed one year later.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT COSTS	62.9	50.0	39.8	40.0	32.4	8.0				233.1
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	62.9	50.0	39.8	40.0	32.4	8.0				233.1
(ESTIMATED CIVIL SERVICE FTEs)	(154)	(113)	(125)	(125)	(101)	(40)				
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	12.3	9.5	11.2	11.5	9.7	4.0				

TDRS Replenishment Spacecraft Program

The Tracking and Data Relay Satellite (TDRS) Replenishment Spacecraft program ensures sufficient spacecraft will be available to continue Space Network operations into the next century. The program provides three additional TDRS satellites and ground terminal modifications through a fixed price, commercial practices contract with Hughes Space and Communications Company. This innovative approach has deleted or greatly reduced Government specifications and documentation requirements, allowing the contractor to substitute commercial practices; this has resulted in efficiencies in both cost and development lead time.

These satellites will incorporate Ka-band frequencies, where space research has a primary allocation, into the high data rate services provided via the high gain, single access antennas. The single access services at S-band and Ku-band will be retained, remaining backward compatible with the existing, first generation TDRS satellites. These satellites will also provide an enhanced multiple access service with data rates up to three megabits per second. The first spacecraft remains on schedule for launch in the third quarter of 1999.

The estimates do not include costs for use of government facilities and general and administrative support used to carry out the program. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification fo: the program within the Space Communications section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
SPACECRAFT DEVELOPMENT AND GROUND TERMINAL MODIFICATIONS	412.9	66.7	17.7	14.5	57.7	6.5				576.0
LAUNCH SERVICES	76.7	30.2	14.0	40.5	67.8	37.0				266.2
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	489.6	96.9	31.7	55.0	125.5	43.5				842.2
(ESTIMATED CIVIL SERVICE FTEs)	(178)	(37)	(43)	(42)	(42)	(42)	(7)			
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	12.0	3.1	3.8	3.9	4.0	4.2	0.7			

Chandra X-ray Observatory

The Chandra X-ray Observatory (CXO, formerly the Advanced X-ray Astrophysics Facility, AXAF) is the third of NASA's Great Observatories, which include the Hubble Space Telescope and the Compton Gamma Ray Observatory. CXO observes matter at the extremes of temperature, density and energy content. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, CXO is providing unique and crucial information on the nature of objects ranging from nearby stars to quasars at the edge of the observable universe. The AXAF program was restructured in 1992 in response to decreasing future funding projections for NASA programs. The original baseline was an observatory with six mirror pairs, a 15-year mission in low-Earth orbit, and shuttle servicing. The restructuring produced AXAF-I, an observatory with four mirror pairs to be launched into a high-Earth orbit for a five-year lifetime, and AXAF-S, a smaller observatory flying an X-Ray Spectrometer (XRS). A panel from the National Academy of Sciences (NAS) endorsed the restructured AXAF program. The FY 1994 AXAF budget was reduced by Congress, resulting in termination of the AXAF-S mission. The Committees further directed that residual FY 1994 AXAF-S funds be applied towards development of a similar instrument for flight on the Japanese Astro-E mission. Astro-E is scheduled to be launched by Japan in February 2000. In December 1998 NASA announced that AXAF had been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. CXO was launched successfully by the Space Shuttle and an Inertial Upper Stage on July 23, 1999.

The budgetary estimates provided below encompass: the early development of the mirror technology; the design and development phase; establishment of a mission-unique science center and preflight ground system development, followed by a five-year period (1999-2008) of mission operations and science data analysis; the purchase of the IUS and integration activities; the average cost (including recurring costs for improvements and upgrades) of an FY 1998 Space Shuttle flight; mission-unique tracking and data support costs; and, the construction of the X-Ray Calibration Facility. The estimates below also include a pro forma distribution of the average costs of a Space Shuttle. They do not include the amounts being contributed by international participants, or for the use of non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
ADVANCED TECH DEVELOPMENT	54.2									54.2
DEVELOPMENT	1,469.7	42.0	4.1							
UPPER STAGE	73.9	3.3								77.2
MISSION OPERATIONS	169.9	11.0	5.2	3.6	3.7	3.8	3.7	3.3	15.2	219.4
DATA ANALYSIS		44.5	55.2	55.5	57.2	55.2	53.9	49.1	155.1	525.7
STS LAUNCH SUPPORT	268.0	114.9								382.9
TRACKING & DATA SUPPORT	1.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	3.0
CONSTRUCTION OF FACILITIES	17.7									17.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	2,054.9	215.9	64.7	59.3	61.1	59.2	57.8	52.6	170.4	1,280.1
(ESTIMATED CIVIL SERVICE FTEs) - SSE ONLY	(1,528)	(129)	(33)	(28)	(15)	(15)	(15)	(15)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	96.9	10.1	2.5	2.2	1.1	1.2	1.2	1.3		

Space Infrared Telescope Facility (SIRTF)

The purpose of the Space Infrared Telescope Facility (SIRTF) mission is to explore the nature of the cosmos through the unique windows available in the infrared portion of the electromagnetic spectrum. SIRTF is the fourth of NASA's Great Observatories, which include the Hubble Space Telescope, the Compton Gamma Ray Observatory, and the Advanced X-Ray Astrophysics Facility. The funding plan provided below reflects a dramatic restructuring of the SIRTF design concept carried for many years. Rather than simpl "descoping" the "Great Observatory" concept to fit within a $400 million (FY94 $) cost ceiling imposed by NASA, scientists and engineers have instead redesigned SIRTF from the bottom-up. The goal was to substantially reduce costs associated with every element of SIRTF -- the telescope, instruments, spacecraft, ground system, mission operations, and project management. The Jet Propulsion Laboratory (JPL) was assigned responsibility for managing the SIRTF project. SIRTF is planned for launch on a Delta launch vehicle during FY 2002.

The budgetary estimates below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out prior to FY 96. A more detailed exposition of the progra goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
ATD	79.9									79.9
DEVELOPMENT	70.2	119.7	123.4	117.6	25.6					456.5
MISSION OPS					4.4	7.0	7.3	7.4	23.2	49.3
DATA ANALYSIS					33.9	61.8	61.2	64.0	237.6	458.5
TRACKING & DATA SUPPORT					tbd	tbd	tbd	tbd	tbd	tbd
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	150.1	119.7	123.4	117.6	63.9	68.8	68.5	71.4	260.8	1044.2
(ESTIMATED CIVIL SERVICE FTEs)	(63)	(40)	(32)	(18)	(10)	(4)	(4)	(4)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		3.4	2.9	1.7	1.1	0.5	0.5	0.5		

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)

The TIMED mission is the first science mission in the Solar Terrestrial Probes (STP) Program, and is part of NASA's initiative aimed at providing cost-efficient scientific investigation and more frequent access to space. TIMED is being developed for NASA by the Johns Hopkins University Applied Physics Laboratory (APL). The Aerospace Corporation, the University of Michigan, NASA's Langley Research Center with the Utah State University's Space Dynamics Laboratory, and the National Center for Atmospheric Research will provide instruments for the TIMED mission.

TIMED will be ready for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission. However, due to Jason's inability to meet the May launch date, the TIMED spacecraft is now scheduled for a fall 2000 launch. TIMED began its 36-month C/D development period in April 1997. The budgetary estimates below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out from April 1996 to April 1997. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC TOTAL
DEVELOPMENT	81.6	41.8	21.4						144.8
MISSION OPERATIONS			0.7	2.0	1.0				3.7
DATA ANALYSIS			1.9	9.2	7.7	6.5	2.8	0.3	28.4
LAUNCH SUPPORT	13.1	11.5	6.1						30.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	94.7	53.3	30.1	11.2	8.7	6.5	2.8	0.3	207.6
(ESTIMATED CIVIL SERVICE FTEs)		(24)	(24)	(3)	(3)	(3)	(3)	(3)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		2.0	2.0	0.3	0.3	0.3	0.3	0.3	

Stratospheric Observatory for Infrared Astronomy

The initial development funding for the Stratospheric Observatory for Infrared Astronomy (SOFIA) was requested in the FY 1996 budget. This new airborne observatory will provide a significant increase in scientific capabilities over the Kuiper Airborne Observatory, which was retired in October, 1995. The SOFIA will be accommodated in a Boeing 747 and will feature a 2.5-meter infrared telescope to be provided by the German Space Agency (DARA). SOFIA will conduct scientific investigations at infrared and submillimeter wavelengths. The initial science flights for SOFIA was scheduled to occur in October 2001; however, delays in development of the German telescope assembly have caused science operations to slip until November 2002.

The budget estimates provided below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the costs of preliminary design studies carried out in previous years, the amounts being contributed by the international participants, or costs for the use of government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT	97.1	58.2	39.0	33.9	31.0					259.2
[CONSTRUCTION OF FACILITIES INCLUDED ABOVE]		[7.0]								
MISSION OPERATIONS						42.4	38.3	39.4	CONT.	CONT.
TOTAL EXCLUDING CIVIL SERVICE COSTS	97.1	58.2	39.0	33.9	31.0	42.4	38.3	39.4		
(ESTIMATED CIVIL SERVICE FTEs)		(75)	(78)	(60)	(48)	(40)	(40)	(40)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		5.1	7.0	5.7	5.2	4.8	5.0	5.3		

Relativity Mission/Gravity Probe-B

The development of the Relativity mission began in 1993, after many years of studying mission design alternatives and developing the advanced technologies required for this mission to verify Einstein's theory of general relativity. The award of the spacecraft development contract was made in 1994. The scheduled launch date is September 2001, using a Delta II launch vehicle. This launch date reflects an eleven-month slip from the original baseline date for launch of the Relativity Mission.

The estimates provided below include funding for the experiment development activities, a minimum of 16 months of mission operations, and the launch services. These estimates are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out from FY 1985-87, but they do provide the amounts for the Shuttle Test of Relativity Experiment program initiated in FY 1988 and subsequently restructured into a ground test program only. The estimates also exclude the non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC TOTAL
DEVELOPMENT	388.2	46.5	37.7	13.8					486.2
MISSION OPERATIONS				1.0	1.0	1.0			3.0
DATA ANALYSIS				8.0	5.2	3.1			16.3
LAUNCH SUPPORT	24.1	14.8	12.2						51.1
TRACKING & DATA SUPPORT						TBD			
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	412.3	61.3	49.9	22.8	6.2	4.1	0.0		556.6
(ESTIMATED CIVIL SERVICE FTEs)	(98)	(9)	(10)	(8)	(4)	(2)	(1)	(1)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	6.3	0.8	0.9	0.8	0.4	0.2	0.1	0.1	

The Explorer Program

The Explorer program consists of small to mid-sized spacecraft conducting investigations in all space physics and astrophysics disciplines. The program provides for frequent, relatively low-cost missions to be undertaken as funding availability permits within an essentially level overall funding profile for the program. The funding profile provided below covers the design and development phase, launch services, mission-unique tracking and data acquisition support, mission operations and data analysis. It does not include costs for the use of government facilities and general and administrative support required to implement the program. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC	TOTAL
*Far Ultraviolet Spectroscopy Explorer	143.9	20.2	13.4	14.4	12.0					203.9
*Imager for Magnetospause-to-Aurora Global Explorati	78.8	50.8	6.3	7.1	7.1	2.5	1.0	1.0		154.6
*Microwave Anisotropy Probe	48.5	39.4	32.4	19.5	3.7	2.6	0.7			146.8
*SWAS, TRACE, WIRE	211.9	14.8	5.0	5.5	2.8	2.4	1.0			243.4
*HESSI, GALEX, TWINS (New SMEX)	18.8	60.9	42.2	27.1	9.6	7.3	4.3	2.3	7.2	179.7
*STEDI (SNOE, TERRIERS, CATSAT, CHIPS & IMEX)	36.3	13.7	15.3	8.5	2.5	0.7				77.0
*HETE-II	9.2	11.1	4.7	1.5						26.5
*Planning & Future Developments		6.8	28.4	95.8	162.9	208.1	249.6	314.7	CONT	
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		217.7	147.7	179.4	200.6	223.6	256.6	318.0	CONT	
(ESTIMATED CIVIL SERVICE FTEs)	(2,081)	(246)	(232)	(204)	(187)	(202)	(241)	(241)	CONT	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		22.7	21.7	19.8	19.1	21.3	26.4	27.5	CONT	

*Tracking estimate is not included

Far Ultraviolet Spectroscopic Explorer

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission is to conduct high-resolution spectroscopy in the far ultraviolet region. Major participants include the Johns Hopkins University, the University of Colorado, and University of California, Berkeley. Orbital Sciences Corporation was selected by JHU as the spacecraft developer. Canada provided the fine error sensor assembly, and France provided holographic gratings. GSFC provided management oversight of this Principal Investigator managed mission. FUSE launched successfully in June 1999 aboard a Delta-II launch vehicle.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC	TOTAL
DEVELOPMENT	106.5	13.9								120.4
LAUNCH SUPPORT	37.1	0.7								37.8
MISSION OPERATIONS		3.3	6.0	5.0	3.2					17.5
DATA ANALYSIS	0.3	2.3	7.4	9.4	8.8					28.2
TOTAL	143.9	20.2	13.4	14.4	12.0					203.9

Imager for Magnetopause-to-Aurora Global Exploration

Development of the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) began in FY 1997. The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute has been selected to develop the IMAGE mission. IMAGE is scheduled for launch in February 2000 aboard a Delta-7326 (Med-Lite Class ELV).

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC	TOTAL
DEVELOPMENT	58.7	25.8								84.5
LAUNCH SUPPORT	20.1	25.0	1.7							46.8
MISSION OPERATIONS			0.2	0.4	0.1					0.7
DATA ANALYSIS			4.4	6.7	7.0	2.5	1.0	1.0		22.6
TOTAL	78.8	50.8	6.3	7.1	7.1	2.5	1.0	1.0		154.6

Microwave Anisotropy Probe

Development of the Microwave Anisotropy Probe (MAP) began in FY 1997. The MAP mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. MAP will launch in November 2000 aboard a Delta-7326 (Med-Lite Class ELV).

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC	TOTAL
DEVELOPMENT	40.9	18.3	17.7	10.4						87.3
LAUNCH SUPPORT	7.6	21.1	14.7	4.7						48.1
MISSION OPERATIONS				1.0	0.9	0.8				2.7
DATA ANALYSIS				3.4	2.8	1.8	0.7			8.7
TOTAL	48.5	39.4	32.4	19.5	3.7	2.6	0.7			146.8

Mars Surveyor Program

The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. The first mission in this program, the Mars Global Surveyor mission, was approved as a new start in FY 1994. The follow-on Mars Surveyor 98 Climate Orbiter (MCO) and Polar Lander (MPL) were approved in FY 1995. In light of the failed MCO and MPL, the entire Mars Surveyor Program is undergoing major re-planning activity. Detail on the revised schedules and outputs will be provided once the re-planning is completed.

Funding also supports Mars Micromissions and Mars Telecom Network. Mars Micromissions will enhance the science return from Mars missions by utilizing micro-spacecraft launched as secondary payloads on commercial French Ariane-V geosynchronous transfer missions. Mars Telecom Network is designed to support Mars global reconnaissance, surface exploration, sample return missions, robotic outposts, and eventual human exploration by: 1) Developing a communications capability to provide a substantial increase in data rates and connectivity from Mars to Earth; (2) Developing an in-situ navigation capability to enable more precise targeting and location information on approach and at Mars.

Funding in the Future Missions budget line provides for Mars missions in the 2001 and beyond launch opportunities, and technologies required for these future Mars missions.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC	TOTAL
MARS GLOBAL SURVEYOR	207.5	13.0	15.6	9.5	9.1	4.2	2.8	2.2		263.9
98 MARS ORBITER/LANDER	262.8	27.2	5.6	10.4	7.3	3.5				316.8
MICROMISSION & TELECOM			6.0	35.0	33.0	87.0	146.0	137.0		
FUTURE MISSIONS (includes '01 and future Missions)	75.2	210.7	242.4	300.7	295.5	309.3	294.5	308.0	Cont.	
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	545.5	251.0	269.6	355.6	344.9	404.0	443.3	447.2	Cont.	
(ESTIMATED CIVIL SERVICE FTEs)		(48)	(60)	(52)	(38)	(36)	(31)	(31)	Cont.	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		4.1	4.7	4.5	3.7	3.6	3.4	3.6	Cont.	

Mars Global Surveyor

This mission will obtain a majority of the expected science return from the lost Mars Observer mission by flying a science payload comprised of spare Mars Observer instruments aboard a small, industry-developed spacecraft. Launch occurred in November 1996 on a Delta II launch vehicle, and MGS entered Mars orbit in September 1997. The funding estimates provided below do not include the previous expenditures on spare Mars Observer instruments or the amount recovered from the prime contractor after the Mars Observer failure.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC TOTAL
DEVELOPMENT	130.7								130.7
LAUNCH SUPPORT	52.6								52.6
MISSION OPERATIONS	17.9	6.0	11.2	4.7	3.2	3.2	1.8	1.5	49.5
DATA ANALYSIS	6.3	7.0	4.4	4.8	5.9	1.0	1.0	0.7	31.1
TOTAL	207.5	13.0	15.6	9.5	9.1	4.2	2.8	2.2	263.9

98 Mars Orbiter/Lander

The '98 Mars Orbiter and Lander consisted of the Mars Climate Orbiter (MCO) and the Mars Polar Lander (MPL). MCO was intended to study the planet's weather for one Martian year, acquiring data to help scientists better understand the Martian climate. The MPL was to focus primarily on Mars' climate and water. The MPL mission would search for near-surface ice and possible surface records of cyclic climate change, and characterize physical processes key to the seasonal cycles of water, carbon dioxide and dust on Mars. MCO launched in December 1998 and MPL launched in January 1999; however, both missions failed upon arrival at Mars.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC TOTAL
DEVELOPMENT	179.8	9.2							189.0
LAUNCH SUPPORT	83.0	7.7							90.7
MISSION OPERATIONS		9.4	3.6	8.9	6.4	3.5			31.8
DATA ANALYSIS		0.7	1.6	1.2	0.9				4.4
TRACKING & DATA SUPPORT		0.2	0.4	0.3					0.9
TOTAL	262.8	27.2	5.6	10.4	7.3	3.5			316.8

Future Surveyor Missions

The Mars Surveyor landers planned in future years -- 2001, 2003, 2005 and beyond -- will capitalize on the experience of the Mars Pathfinder lander mission launched in November 1996.

In light of the failed MCO and MPL, the entire Mars Surveyor Program is undergoing major re-planning activity. Detail on the revised schedules and outputs will be provided once the re-planning is completed.

(Budget Authority in Millions of Dollars)

	PRIOR	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	BTC TOTAL
DEVELOPMENT	75.2	169.0	222.7	248.1	245.4	264.6	266.1	277.7	cont.
LAUNCH SUPPORT		41.7	19.7	43.6	35.1	22.4			cont.
MISSION OPERATIONS				8.0	11.8	19.9	20.4	17.2	cont.
DATA ANALYSIS				1.0	3.2	2.4	8.0	13.1	cont.
TRACKING & DATA SUPPORT									
TOTAL	75.2	210.7	242.4	300.7	295.5	309.3	294.5	308.0	

Discovery Missions

Discovery missions are planetary exploration missions designed with focused science objectives that can be met with limited resources. Total development costs are not to exceed $150 million in constant FY 1992 dollars, and development schedules are limited to three years or less.

The budgetary estimates provided below are the amounts included in the specific budget justification for this program within the Space Science section in the Science, Aeronautics and Technology appropriation. Under the specific mission descriptions, see below, other direct program cost elements are included: the development of the spacecraft and experiments, one year of mission operations, the launch services, and unique tracking and data acquisition services. They do not include costs for the use of government facilities and general and administrative support required to implement the program. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
NEAR	187.7	14.5	13.2	8.2						223.6
LUNAR PROSPECTOR	61.7	2.2								63.9
STARDUST	145.9	24.8	4.3	4.0	3.7	5.0	6.2	9.0	2.6	205.5
GENESIS	44.4	82.9	50.2	18.0	6.9	7.4	2.8	2.1	1.8	216.5
CONTOUR	0.4	8.8	51.8	45.6	21.1	3.7	3.0	1.8	8.1	144.3
FUTURE MISSIONS		28.7	86.7	163.5	225.8	223.3	263.4	283.1	CONT	
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		161.9	206.2	239.3	257.5	239.4	275.4	296.0		
(ESTIMATED CIVIL SERVICE FTEs)		(20)	(19)	(17)	(17)	(16)	(16)	(16)	Cont.	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		2.3	2.0	1.9	2.0	1.8	1.9	2.2	Cont.	

Near-Earth Asteroid Rendezvous (NEAR)

The NEAR was approved as a new start in FY 1994 as one of the initial Discovery Program missions. The NEAR mission was conducted as an in-house effort at the Applied Physics Laboratory, with many subcontracted subsystems. The NEAR spacecraft will conduct a comprehensive study of the near-Earth asteroid 433 Eros, including its physical and geological properties and its chemical and mineralogical composition. The NEAR spacecraft was launched February 17,1996 on a Delta II launch vehicle. The original opportunity to rendezvous with the asteroid in January 1999 was lost when the spacecraft failed to fire its main engine properly. However, subsequent firing was successful, and NEAR will rendezvous with Eros in February 2000.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC TOTAL
DEVELOPMENT	124.9								124.9
LAUNCH SUPPORT	43.5								43.5
MISSION OPERATIONS	10.9	8.4	6.6	5.0					30.9
DATA ANALYSIS	8.1	5.9	6.4	3.0					23.4
TRACKING & DATA SUPPORT	0.3	0.2	0.2	0.2					0.9
TOTAL	187.7	14.5	13.2	8.2					223.6
(ESTIMATED CIVIL SERVICE FTEs)		(4)	(4)						
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		0.8	0.5						

Lunar Prospector

Lunar Prospector was selected as the third Discovery mission in FY 1995, and Phase C/D development started in the first quarter of FY 1996. The mission was designed to search for resources on the Moon, with special emphasis on the search for water in the shaded polar regions. Ames Research Center managed the mission, and Lockheed Martin provided the spacecraft, instruments, launch and operations. Launch on a Lockheed Launch Vehicle-II (LLV-II) occurred in January 1998, and the mission has been completed successfully. Launch costs are included in the development cost.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC TOTAL
DEVELOPMENT	56.6								56.6
MISSION OPERATIONS	1.8	0.5							2.3
DATA ANALYSIS	3.3	1.7							5.0
TOTAL	61.7	2.2							63.9

Stardust

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory. The mission team completed the Phase B analysis, and Stardust was approved for implementation in October 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. The mission will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust is using a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, the spacecraft carries three additional scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) was provided by Germany to perform basic compositional analysis of the samples while in flight; and a dust flux monitor will be used to sense particle impacts on the spacecraft. Stardust was launched on the Med-Lite expendable launch vehicle in February 1999, and is operating well. Return of the samples to Earth is expected in January 2006.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
PHASE A/B	9.6									9.6
DEVELOPMENT	108.0	8.8								116.8
LAUNCH SUPPORT	28.3	12.5								40.8
MISSION OPERATIONS		1.0	1.0	1.0	1.0	1.2	1.2	1.3	1.0	8.7
DATA ANALYSIS		2.5	3.3	3.0	2.7	3.8	5.0	7.7	1.6	29.6
TOTAL	145.9	24.8	4.3	4.0	3.7	5.0	6.2	9.0	2.6	205.5

Genesis

In October 1997 NASA selected Genesis as the fifth Discovery mission. The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. It is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA; JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, it will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
PHASE A/B	11.4									11.4
DEVELOPMENT	33.0	65.1	33.2	7.3						138.6
LAUNCH SUPPORT		17.8	17.0							34.8
MISSION OPS				2.0	1.2	1.4				4.6
DATA ANALYSIS				8.2	5.2	5.5	2.8	2.1	1.8	25.6
TRACKING & DATA SUPPORT				0.5	0.5	0.5				1.5
TOTAL	44.4	82.9	50.2	18.0	6.9	7.4	2.8	2.1	1.8	216.5
(ESTIMATED CIVIL SERVICE FTEs)		(5)	(4)	(4)	(4)	(4)	(4)	(4)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		0.5	0.4	0.4	0.4	0.5	0.5	0.5		

Comet Nucleus Tour (CONTOUR)

In October 1997 NASA selected CONTOUR as the sixth Discovery mission. CONTOUR's goals are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future "new" comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management will be provided by the Johns Hopkins University Applied Physics Laboratory of Laurel, MD. Launch is expected in June 2002.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
PHASE A/B	0.4	8.8								9.2
DEVELOPMENT			34.9	26.0	8.2					69.2
LAUNCH SUPPORT			16.9	19.6	10.8					47.2
MISSION OPS					1.0	1.0	1.0	1.0	2.0	6.0
DATA ANALYSIS					1.1	2.7	2.0	0.8	6.1	12.7
TRACKING & DATA SUPPORT					TBD	TBD	TBD	TBD	TBD	TBD
TOTAL	0.4	8.8	51.8	45.6	21.1	3.7	3.0	1.8	8.1	144.3
(ESTIMATED CIVIL SERVICE FTEs)		(4)	(4)	(6)	(6)	(5)	(5)	(5)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		0.3	0.4	0.6	0.6	0.5	0.6	0.6		

Space Science Flight Validation Spacecraft

The Flight Validation (formerly called New Millennium) program is an advanced development effort started in FY 1996 to demonstrate how complex scientific spacecraft can be built for lower mission costs and have short development times, while still possessing considerable scientific merit. The Flight Validation program will enable the introduction of the latest technology advances into spacecraft for Space Science missions. The primary objectives of the program are to increase the performance capabilities of spacecraft and instruments while simultaneously reducing total costs of future science missions, thereby allowing more frequent flight opportunities even under tight budget constraints. In previous years, NASA and the Department of Defense have funded technology developments offering extraordinary promise, and the goal of this program is to move those technologies from the laboratory to space.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. The program is designed as an ongoing program to include development and launch of two small ($40-50 million each) and one medium ($100-150 million) system validations every four years along with two-to-three subsystem validations per year ($100-150 million). Launches are generally targeted for small expendable launch vehicles. The budget estimate below does not include the costs for the government facilities and general and administrative support used to carry out the research and development activities. Additional information on the Deep Space 1, Deep Space 2 and Space Technology 5 missions is provided later in this section. A more detailed description of the program goals, objectives and activities is provided in the budget justification narrative for the Space Science Supporting Research and Technology program.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEEP SPACE 1	140.9	13.8	4.9	5.8	0.6					166.0
DEEP SPACE 2	26.5	2.4	0.8							29.7
SPACE TECHNOLOGY 5		6.0	3.1	8.0	6.0	4.0	1.5			28.6
FUTURE MISSIONS INCLUDING PROGRAM COSTS	27.2	10.0	7.0	30.0	38.8	60.9	79.6	83.0	CONT	
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		32.2	15.8	43.8	45.4	64.9	81.1	83.0	CONT	
(ESTIMATED CIVIL SERVICE FTEs)	(322)	(8)	(1)	(1)	(1)	(1)	(1)	(1)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	4.1	0.7	0.1	0.1	0.1	0.1	0.1	0.1		

Deep Space 1

Deep Space 1 was selected in FY 1996 as the first New Millennium Program mission. DS 1 launched in October, 1998 on a Med-Lite-class Delta launch vehicle. All technologies completed their validation by the end of FY 1999 and included solar electric propulsion, an advanced solar array, autonomous primary navigation, and a miniature imaging camera spectrometer. Given the opportunity to explore further, the DS 1 mission has been extended to validate twelve advanced technologies via an asteroid flyby and comet flyby. The supplemental technology development line below contains funding for crosscutting technology development efforts previously managed by the Office of Space Access and Technology.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT	95.2	4.1								99.3
SUPPLEMENTAL TECH DEV (included in Dev)	[14.9]									[14.9]
MISSION OPERATIONS		8.1	3.0	4.2						15.3
DATA ANALYSIS		1.5	1.9	1.6	0.6					5.6
LAUNCH SUPPORT	45.4									45.4
TRACKING & DATA SUPPORT	0.3	0.1								0.4
TOTAL	140.9	13.8	4.9	5.8	0.6	0.0	0.0	0.0	0.0	166.0

Deep Space 2

Deep Space 2 was selected in FY 1996 to develop and validate technologies and systems required to deliver multiple small packages to the surface and/or subsurface of Mars using direct entry. Technologies to be validated included power electronics, a microcontroller, flexible interconnects for system cabling and a sample/water experiment. DS 2 was attached to ("piggyback" on) the Mars 98 Lander, launched in January 1999. The probes were to have impacted Martian soil on December 3, 1999 but each failed to respond to communication efforts by NASA engineers.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2001	2003	2004	2005	BTC	TOTAL
DEVELOPMENT	26.2	1.4								27.6
SUPPLEMENTAL TECH DEV (included in Dev)	[3.3]									[3.3]
MISSION OPERATIONS		0.5	0.4							0.9
DATA ANALYSIS	0.3	0.5	0.4							1.2
ELV INTEGRATION (included in Dev)	[1.6]									[1.6]
TOTAL	26.5	2.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	29.7

Space Technlogy 5

Three very small satellites called the Nanosat Constellation Trailblazer mission were selected in August 1999 as Space Technology 5. Each Trailblazer spacecraft is about the size of a large birthday cake, they weigh about as much as a desktop computer and are smart enough to fly in formation far from Earth as they test new technologies. The mission will validate methods of operating several spacecraft as a system and test eight technologies in the harsh space environment near the boundary of Earth's protective magnetic field, or magnetosphere. The mission will be launched in 2003 as a secondary payload on an expendable launch vehicle.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	BTC	TOTAL
DEVELOPMENT		6.0	3.1	8.0	6.0	3.2				26.3
MISSION OPERATIONS						0.5	0.2			0.7
DATA ANALYSIS						0.3	1.3			1.6
LAUNCH SUPPORT										
TOTAL		6.0	3.1	8.0	6.0	4.0	1.5	0.0	0.0	28.6

Earth Observing System

Before the Earth Observing System (EOS) was authorized in November 1990 in the FY 1991 budget as a new start, EOS planning had been in progress for over eight years. The EOS is key to achieving the objectives set forth in the Earth science program plan and the overall goal and scientific objectives of the interagency U.S. Global Change Research Program. EOS is an international science program, drawing upon the contributions of Europe (ESA), Canada, and Japan both in terms of spacecraft and instruments. This extraordinary collaboration is essential to reach the objective of providing comprehensive measurements of the nature of global climate change.

At its outset, the EOS program was based on the flights of two series of large platforms, in addition to platforms from Japan and ESA and instruments carried on Space Station Freedom. The initial estimates provided to Congress focused on the period through fiscal year 2000. The initial estimate of $18-21 billion included development, mission operations, data analysis, launch services, communications, construction of facilities and the amounts carried in the Space Station program for the polar platform's development. In the FY 1992 appropriations process, Congress directed NASA to modify the scope and cost of the program. The cost through FY 2000 was to be reduced by $5 billion, the FY 1993 funding level had to be reduced, and NASA was to examine the feasibility of using smaller platforms. In 1991, the program was restructured to employ five smaller flight series. In 1992, in response to the constrained budget environment, NASA further rescoped the program by implementing a common spacecraft approach for all flights after the first morning (AM-1) spacecraft, increasing reliance on the cooperative efforts of international and other government agencies, and adopting a build-to-cost approach for the first unit of a multiple instrument build. The estimated NASA funding through FY 2000 was further reduced to $8.0 billion in this effort.

In the FY 1995 budget process, the program cost estimate was further adjusted downward by approximately $0.9 billion, of which $0.3 billion reflected an accounting transfer for small business innovative research out of individual programs into a common NASA account, and $0.1 billion reflected the change to lower-cost launch vehicles. The further reductions in program funding were addressed in 1994 through a program rebaselining activity. A number of small spacecraft were introduced into the program flight plans. In addition, alterations were made in flight phasing and accommodations were provided for a follow-on instrument to the enhanced thematic mapper being flown in 1999 on Landsat-7. Funding for the science investigations and data analysis was separated from the algorithms being developed to convert the instrument data into information. This change recognized the close relationship to similar science investigations and data analysis funded in the Earth Science research and analysis account. (The amounts budgeted for EOS science are shown in the table below.) In addition, it was decided to incorporate the development funding for the Landsat-7 into the EOS program in light of the integral ties between the two activities.

In the FY 1996 budget process, the amounts reflected the related program costs for Landsat-7 activities previously funded by the Department of Defense.

The 1997 Biennial Review completed the shift in planning for future missions that began in the 1995 "reshaping" exercise. Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive, approach to acquiring Earth science data.

The ESE recognizes that the pathways of global change research lead from specialized studies of fundamental processes to the integration of individual findings into interactive models of the global Earth system, which can eventually deliver reliable predictions of natural or human-induced environmental phenomena. Long, consistent time-series of global environmental measurements are needed to document changes in forcing parameters and corresponding variations in the state of the Earth system, as required to explore the range of natural variability and test mathematical models of the phenomena. While diagnostic studies based long time series of global measurements can reveal the nature of the underlying mechanisms, focused process studies are indispensable to identify and model the basic physical, chemical and biological processes involved. Understanding these component processes is crucial in order to achieve the goal of constructing reliable predictive models of the Earth system. For this reason, the ESE aims to achieve a proper balance between long-term systematic measurements of key forcing or response parameters, and specialized process research. NASA ESE is in the process of developing a science implementation plan, which will drive the selection of the EOS follow-on missions.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation except for the amount for the Space Station platform. The amounts below reflect the effects of the rescoping of the EOS program, the impacts of the ZBR, and the inclusion of the estimate for FY 2005. They do not include the costs of the non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Earth Science section.

(Budget Authority in Millions of Dollars)

Earth Observing System	Prior	1999	2000	2001	Subtotal Through FY 2000	2002	2003	2004	2005	Total Through FY 2004
MORNING (Terra)	1,176.6	36.0	6.2	3.1	1,221.9					1,221.9
AFTERNOON (Aqua)	630.3	113.1	92.8	42.9	879.1					879.1
CHEMISTRY	206.1	132.8	124.7	110.3	573.9	69.1	26.2	0.1		669.3
SPECIAL SPACECRAFT	372.3	116.0	120.4	86.7	695.4	32.2	15.8	13.8	13.5	770.7
QUIKSCAT	72.9	11.4	1.1		85.4					85.4
LANDSAT 7	422.3	17.0	9.6	1.4	450.3	1.7	1.7	1.9		455.6
EOS FOLLOW-ON	3.9	4.5	24.4	120.6	153.4	203.3	268.5	228.7	203.0	1,056.9
ALGORITHM DEVELOPMENT	436.2	116.8	121.7	82.1	756.8	70.4	56.9	53.9	52.6	990.6
TECHNOLOGY INFUSION *	168.5	89.0	74.5	89.1	421.1	74.2	53.4	93.3	115.8	757.8
EOSDIS	1,345.1	261.7	261.9	252.0	2,120.7	249.2	255.2	282.1	266.3	3,173.5
SUBTOTAL	4,834.2	898.3	837.3	788.2	7,358.0	700.1	677.7	673.8	651.2	10,060.8
PHASE B	41.0				41.0					41.0
SPACE STATION PLATFORM	104.0				104.0					104.0
EOS SCIENCE		46.4	60.3	59.2	165.9	65.6	66.0	66.9	69.5	433.9
LAUNCH SERVICES	278.0	4.2			282.2					282.2
CONSTRUCTION OF FACILITIES	96.7				96.7					96.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	5,353.9	948.9	897.6	847.4	8,047.8	765.7	743.7	740.7	720.7	11,018.6
(ESTIMATED CIVIL SERVICE FTEs)	(3,616)	(610)	(608)	(689)		(720)	(716)	(741)	(741)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	250.8	51.9	54.1	63.4		70.2	73.2	79.4	83.2	

* In FY 01 Submit, Technology Infusion moved to R&T.

EOS New Millennium Program and Technology Infusion

The New Millennium Program (NMP) and Technology Infusion budget reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs. The program objectives are to spawn "leap ahead" technology by applying the best capabilities available from several sources within the government, private industries and universities. The first mission EO-1, has been selected to demonstrate innovative technology to produce Landsat data. The Space-Readiness Coherent Lidar Experiment (Sparcle) was the second EO mission. The project was terminated due to cost growth. However, the progress in the lidar technology development is still useful for future remote systems.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	TOTAL
EO-1 (INCLUDES LAUNCH SERVICES)	115.3	47.3	3.0	2.4					168.0
EO-2 SPARCLE (STS ATTACHED PAYLOAD)	7.3	4.1							11.4
NMP TECHNOLOGY & FUTURE FLIGHTS (INCLUDES LAUNCH SERVICES)	17.5	4.7	34.1	47.7	35.8	13.1	53.0	75.5	281.4
ADV. INFORMATION SYSTEMS TECH.		6.5	12.6	14.0	9.5	9.8	9.8	9.8	72.0
SENSOR & DETECTOR TECHNOLOGY	16.5	5.5	9.8	10.0	8.9	8.5	8.5	8.5	76.2
INSTRUMENT INCUBATOR	11.9	20.9	15.0	15.0	20.0	22.0	22.0	22.0	148.8
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	168.5	89.0	74.5	89.1	74.2	53.4	93.3	115.8	757.8
(ESTIMATED CIVIL SERVICE FTEs)	(126)	(98)	(15)						
CIVIL SERVICE COMPENSATION ESTIMATE	9.9	8.0	1.4						

Earth Probes

The Earth Probes program is the component of Earth Science that addresses unique, specific, highly focused mission requirements in Earth science research. The program is designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts, small satellites and advanced technical innovation. Earth Probes complement the Earth Observing System by enabling investigations needing special orbits or other unique requirements. The missions are developed using short cycles of 1-3 years. The currently approved Earth Probes are the Total Ozone Mapping Spectrometer (TOMS), Triana, and Earth System Science Pathfinders (ESSP) missions. NASA has added the University Class Earth System Science (UnESS) pathfinder to the Earth Probes program. The Experiments of Opportunity funding will accommodate opportunities to provide flight instruments and technologies on non-Earth science missions, foreign or domestic, or on airborne experiments. The Lewis and Clark missions were transferred from the Office of Space Access and Technology when that office was dissolved. The LightSAR was cancelled in FY 1999; however, SAR studies will continue under the Technology Infusion Program. The SRTM is a reimbursable mission with the National Imaging and Mapping Agency (NIMA). In FY 2000 NASA has requested funding for costs associated with SRTM cost growth.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. The program is designed as an ongoing program. The budget estimates immediately below do not include the estimated costs incurred by the international collaborators, mission operations, science costs, related funding included in the Earth Observing System program, use of government facilities and general and administrative support used to carry out the research and development activities. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Earth Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	TOTAL
TOTAL OZONE MAPPING SPECTROMETER (TOMS)	117.4	9.9	24.8	0.5					152.6
NASA SCATTEROMETER (NSCAT)	210.0								210.0
TROPICAL RAINFALL MEASURING MISSION (TRMM)	246.0								246.0
TRIANA	0.9	35.0	35.1	2.0	2.0				75.0
LEWIS & CLARK	130.4								130.4
(UNESS)			2.0	11.5	12.0	19.5	14.5	20.7	Continues
EARTH SYSTEM SCIENCE PATHFINDERS	37.8	62.3	94.5	105.9	125.6	120.7	108.2	121.6	Continues
LIGHTSAR/SAR DEVELOPMENT	12.0								12.0
EXPERIMENTS OF OPPORTUNITY	2.9	2.1	1.0	0.5	0.5	0.4	0.5	0.5	Continues
SRTM			6.2						6.2

Total Ozone Mapping Spectrometer

The TOMS Earth Probes project is a follow-on to the Total Ozone Mapping Spectrometer (TOMS) instrument flown with such great success on the Nimbus-7 spacecraft in 1978. A TOMS instrument was also flown on the Russian METEOR spacecraft in 1991. The TOMS program consists of a set of instruments (flight models 3, 4, 5) and one small spacecraft. Flight model 3 was launched on the TOMS Earth probe spacecraft on July 2, 1996. Flight model 4 was launched on the Japanese ADEOS spacecraft on August 17, 1996. The ADEOS-I spacecraft failed on June 30, 1997. Flight model 5 has been completed, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency has completed its re-planning and will fly FM-5, as QuikToms, on a U.S. vehicle and spacecraft in August 2000.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	TOTAL
DEVELOPMENT	117.4	9.9	24.8	0.5					152.6
MISSION OPERATIONS		2.7	3.2	4.4	2.7	2.7			15.7
SCIENCE TEAMS		0.9	1.0	1.1	1.1	1.0	1.1	1.1	7.3
SELV	16.7								16.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	134.1	13.5	29.0	6.0	3.8	3.7	1.1	1.1	192.3
(ESTIMATED CIVIL SERVICE FTEs)	(149)	(10)	(10)	(7)	(5)	(6)	(4)	(4)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	10.0	0.9	0.9	0.6	0.6	0.6	0.4	0.5	

Tropical Rainfall Measuring Mission

The Tropical Rainfall Measuring Mission (TRMM) was launched aboard the Japanese H-II vehicle November 27, 1997. The TRMM development began in FY 1992, after a four-year period of concept studies and preliminary mission definition. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. TRMM data will be useful to understand the ocean-atmosphere coupling, especially in the development of El Niño events, which form in the tropics but whose effects are felt globally. The observatory spacecraft was built in-house at the Goddard Space Flight Center. The Japanese built a critical instrument, the Precipitation Radar. Two other instruments are being developed with TRMM program funding, the Visible and Infrared Scanner and TRMM Microwave Imager. In 1992, two EOS-funded instruments were added to the payload, the Clouds and Earth's Radiant Energy System (CERES) and the Lightning Imaging Sensor (LIS). The budget estimates provided below include the costs of accommodating these two instruments on the TRMM observatory. The EOS Data and Information System will have a specific capability for disseminating TRMM data.

(Budget Authority in Millions of Dollars)

	PRIOR	1999	2000	2001	2002	2003	2004	2005	TOTAL
DEVELOPMENT	246.0								246.0
EOS-FUNDED INSTRUMENTS/SCIENCE/DIS	[59.0]	[12.6]							[71.6]
MISSION OPERATIONS		10.9	11.0	9.7	2.2				33.8
SCIENCE TEAMS		14.3	14.4	19.4	8.8	0.6			57.5
RESEARCH & ANALYSIS-FUNDED SCIENCE	35.4								35.4
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	281.4	25.2	25.4	29.1	11.0	0.6			372.7
(ESTIMATED CIVIL SERVICE FTEs)	(706)	(22)	(22)	(20)	(17)	(6)	(6)	(6)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	47.5	2.7	2.3	2.3	2.0	0.9	0.8	0.8	

International Space Station

In FY 1983, NASA received approval to enter into a preliminary definition phase of a space station. A cost target was established at that time by President Reagan; this target provided guidance to the team undertaking the definition of what capabilities a space station could have for this amount of money. Due to the uncertainty of future inflation, the target was expressed in constant 1984 dollars. The target value of $8 billion was intended to cover the costs which would be incurred to perform the preliminary definition and the development of space station hardware and ground systems. The President also directed NASA to solicit the involvement of international parties in the space station.

After three years studying numerous design concepts, a final reference design was established by NASA and our international partners--Japan, Canada, and the member nations of the European Space Agency. Prior to requesting from the Administration and Congress the authority to proceed into the development phase, NASA undertook a comprehensive cost estimate. The resultant estimate of $14.5 billion (expressed in 1984 dollars for comparison purposes) was presented to the Administration in early 1987. After consideration, the Administration directed a National Research Council (NRC) review of the reference design and the cost estimate. The NRC reported back that the space station could be built in two phases, with the second phase adding the dual keel configuration, the co-orbiting platform, servicing capabilities, and additional solar dynamic power modules. The NRC included in its estimate of $21.0-25.0 billion (1984 dollars), a number of additional cost elements: operations, marginal Shuttle flight costs, a crew rescue vehicle, civil service salaries and expenses, facilities, and provision for additional testing and backup hardware. These estimates were furnished to the Congress in mid-1987 for their review prior to action on NASA's FY 1988 appropriation.

Over each ensuing year, Congress approved continuation of the Space Station Freedom program, but reduced each year's appropriations request. On several occasions, Congress directed NASA to redesign the Station to conform not only to the reduced appropriations request in that year but also to reduced projections of future funding availability for NASA's overall budget. In early 1993, President Clinton directed NASA to undertake a 90 day study of lower cost redesign options for the Space Station, and appointed an Advisory Committee on the Redesign of the Space Station. In June 1993, upon receiving the final reports and the Advisory Committee's recommendations, President Clinton selected an option (A) from the three options presented and directed NASA to execute the Space Station program for no greater than $2.1 billion per year. This figure encompassed not only the development and operational costs of the Space Station itself but also the costs for a program of precursor scientific research, the expenses for integrating the Space Shuttle and the Space Station and the development of experimental facilities and capabilities for the Space Station. The cap excluded the costs of civil service salaries and expenses, Space Shuttle operational flight costs, and performance improvements to the Shuttle.

In the Fall of 1993, with the U.S. playing the lead role, the international partnership invited the Russian Government to become a participant in the program. The Russians offered access to their Mir space station in the interim period between 1995 and the beginning of the international Space Station's assembly. The Congress and Administration agreed in late 1993 that the $100 million amount to be paid annually to the Russian Space Agency for hardware and services over the FY 1994-97 period was outside the $2.1 billion annual cap. Since late 1993, the U.S. and the newly expanded set of international partners have proceeded with the final design and hardware development for an international Space Station with significantly greater capabilities for research than those which would have been provided on Space Station Freedom, or the option selected in the redesign process.

The budgetary estimates provided below include the amounts for this program in several appropriation accounts. Previous budgets provided funding for Space Station in the Human Space Flight appropriation, and through FY 1997, related research and payloads were funded in the Science, Aeronautics and Technology appropriation. In the FY 1998 budget NASA consolidated the management of Space Station research and technology, science utilization, and payload development with the Space Station development and operations program in order to enhance the integrated management of the total content of the program budget. The FY 2001 budget continues to reflect that consolidation by funding the total program budget in the International Space Station appropriation account. An estimate for an X-38-based crew return vehicle (CRV) is included, with planned funding beginning in FY 2000. Phase 1 of that development is funded within the ISS budget. Phase 2 funding is provided within Aero-Space Technology programs, in the Science, Aeronautics and Technology (SAT) appropriation account, pending a decision on whether to proceed with an X-38-based crew return vehicle, in the context of broader decisions that NASA and the Administration will make regarding future space transportation architectures. Also included in the Space Station project cost estimate is Russian Program Assurance, funding implementation of contingency plans associated with mitigating past, and potential, shortfalls in Russian contributions. The FY 2001 budget proposes multi-year appropriations for the development of the Space Station.

The totals provide the current estimate for the costs to be incurred through the end of FY 2005. A comparison is also included to display annual funding changes from the FY 2000 budget estimate. The estimates do not include the amounts being contributed by the international partners, the $400 million contract with the Russian Space Agency, the costs of the non-program unique NASA facilities, Shuttle performance improvements and flight operations costs, and the general and administrative support used to execute the program. Additionally, the program is planned to achieve an average annual cost target of $1.3 billion when the Space Station becomes operationally mature.

The cost of Space Shuttle flights can be stated in two ways: marginal and annual average. The marginal cost of a given Shuttle flight ranges from $60 million to about $85 million, reflecting the reusable characteristics of the Space Shuttle. The annual average cost of an FY 2001 Shuttle flight is approximately $453 million. Using the annual average costs of the 30 Space Shuttle flights planned for the assembly sequence the present cost estimate for Space Station is approximately $13 billion, including flights for partner elements. An additional 7 Shuttle flights are planned for research and technology utilization purposes during the assembly period; at annual average costs, these utilization flights are estimated at $3 billion. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the budget justifications for the Space Station.

International Space Station *

(Budget Authority in Millions of Dollars)

	PRIOR	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTAL *
PROGRAM ELEMENTS		2,104.7	2,112.9	2,143.6	2,348.6	2,441.3	2,299.7	2,323.1	2,114.5	1,953.5	1,642.5	1,557.0	1,525.0	24,566.4
HUMAN SPACE FLIGHT **	10,234.1	2,104.7	2,112.9	2,143.6	2,348.6	2,441.3	2,299.7	2,323.1	2,114.5	1,858.5	1,452.5	1,327.0	1,275.0	34,035.5
INTERNATIONAL SPACE STATION	10,234.1	2,104.7	2,112.9	2,143.6	2,348.6	2,441.3	2,299.7	2,323.1	2,114.5	1,858.5	1,452.5	1,327.0	1,275.0	34,035.5
VEHICLE	8,234.1	1,765.9	1,559.4	1,618.8	1,694.2	1,604.8	1,183.9	890.1	442.6	345.7	94.7	37.1		19,471.3
OPERATIONS CAPABILITY	956.3	151.0	298.9	247.4	258.3	500.2	576.3	784.6	851.5	786.2	777.7	728.1	722.7	7,639.2
RESEARCH	121.0	187.8	254.6	277.4	196.1	226.3	336.5	394.4	455.4	451.6	535.7	540.8	552.3	4,529.9
RUSSIAN PROGRAM ASSURANCE					200.0	110.0	203.0	200.0	300.0	200.0	44.4	21.0		1,278.4
CREW RETURN VEHICLE								75.0	90.0	75.0				240.0
OTHER	922.7							(21.0)	(25.0)					876.7
SCIENCE, AERO & TECH ***									-	95.0	190.0	230.0	250.0	765.0
(ESTIMATED CIVIL SERVICE FTEs)		(1,283)	(1,441)	(1,934)	(1,852)	(2,204)	(2,136)	(2,385)	(2,328)	(2,294)	(2,148)	(2,035)	(1,915)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M) ****		85.9	102.6	139.6	144.1	180.5	177.6	205.6	204.4	201.0	191.8	197.7	197.0	

* Estimate total is through FY 2005 and reflects the Administration's FY 2001 budget request for International Space Station Multi-Year Appropriations

** The amounts shown have been restated to include the funds appropriated in FY 1997 and prior years to the Science, Aeronautics and Technology, Construction of Facilities, and Research and Development appropriations.

*** Funded in Aero-Space Technology programs for crew return capability, pending decision to implement an X-38-based vehicle, in the context of broader decisions on space transportation architectures; estimate does not assume alternate access to the ISS

**** Civil Service FTEs estimates for the International Space Station include research workforce at non-OSF centers

International Space Station

(Budget Authority in Millions of Dollars)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTAL
FY 2000 BUDGET PROGRAM COST ESTIMATE	**2,104.7**	**2,112.9**	**2,143.6**	**2,348.6**	**2,441.3**	**2,304.7**	**2,482.7**	**2,328.0**	**2,091.0**	**1,721.0**	**1,573.0**		**23,651.5**
FY 2001 BUDGET PROGRAM COST ESTIMATE	**2,104.7**	**2,112.9**	**2,143.6**	**2,348.6**	**2,441.3**	**2,299.7**	**2,323.1**	**2,114.5**	**1,953.5**	**1,642.5**	**1,557.0**	**1,525.0**	**24,566.4**
CHANGE	**+0.0**	-	**+0.0**	-	-	**-5.0**	**-159.6**	**-213.5**	**-137.5**	**-78.5**	**-16.0**	**+1525.0**	**+914.9**
FY 2000 Appropriation: Reduced Request (CRV, ISS ops reserves)							-152.1						-152.1
FY 1999 Operating Plan revision: Transfer to Adv Prog						-5.0							-5.0
FY 2000 Operating Plan revision: Transfer to ELV, recission, transfer from X-38							-7.5						-7.5
FY 2000 request: Rephase/Re-estimate CRV							(-73.0)	-172.0	-60.0	-10.0	+30.0		-212.0
(Amount funded in SAT: Aero-Space Technology)									(95)	(190)	(230)	(250)	(765)
Vehicle make-work changes						+143.7	+106.1	+69.2	+15.6	+0.6	+8.0		+343.2
Operations rephasing						-54.0	+36.4	-3.9	-8.8	+0.4	-8.0		-37.9
Research rephasing/changes						+30.8	-50.3	+1.0	-13.8	-21.8	+2.7		-51.4
RPA rephasing						-45.3	-0.4	-5.9	+22.5	+24.0	+17.0		+11.9
Reserve reductions to offset changes						-75.2	-91.8	-60.4	-15.5	-3.2	-19.7		-265.8
Other Annual Funding Requirements (reserves)							+0.0	-41.5	-77.5	-68.5	-46.0		-233.5

SUMMARY OF BUDGET PLAN BY FUNCTION
(Thousands of Dollars)

	FY 1999 OP PLAN 12/23/1999	FY 2000 OP PLAN REVISED	FY 2001 PRES BUDGET
PERSONNEL AND RELATED COSTS	$1,598,600	$1,683,100	$1,780,400
TRAVEL	$47,800	$51,700	$53,200
RESEARCH OPERATIONS SUPPORT	$463,200	$482,824	$457,000
TOTAL PROGRAM PLAN	**$2,109,600**	**$2,217,624**	**$2,290,600**

DETAIL OF BUDGET PLAN BY FUNCTION
(Thousands of Dollars)

	FY 1999	FY 2000	FY 2001
		(Thousand of Dollars)	
I. Personnel and related costs	**$1,598,600**	**$1,683,100**	**$1,780,400**
A. Compensation and benefits	$1,542,600	$1,624,300	$1,728,500
1. Compensation	$1,266,700	$1,339,800	$1,419,800
2. Benefits	$275,900	$284,500	$308,700
B. Supporting costs	$56,000	$58,800	$51,900
1. Transfer of personnel	$7,900	$13,200	$7,400
2. Investigative services	$2,200	$3,600	$2,100
3. Personnel training	$45,900	$42,000	$42,400
II. Travel	**$47,800**	**$51,700**	**$53,200**
A. Program travel	$30,000	$32,100	$32,600
B. Scientific and technical development travel	$6,000	$6,800	$7,000
C. Management and operations travel	$11,800	$12,800	$13,600
III. Research operations support	**$463,200**	**$482,824**	**$457,000**
A. Facilities services	$130,100	$130,224	$121,500
B. Technical services	$193,300	$211,100	$190,000
C. Management and operations	$139,800	$141,500	$145,500
Total	**$2,109,600**	**$2,217,624**	**$2,290,600**

DISTRIBUTION OF BUDGET PLAN BY FUNCTION BY INSTALLATION
(Thousands of Dollars)

FUNCTION	TOTAL NASA	JSC	KSC	MSFC	SSC	GSFC	ARC	DFRC	LARC	GRC	HQS
PERSONNEL AND RELATED COSTS											
FY 1999	1,598,600	285,200	150,400	227,800	20,000	274,000	138,700	49,600	184,800	163,200	104,900
FY 2000	1,683,100	291,400	160,000	236,100	22,600	285,300	141,600	53,100	198,500	170,400	124,100
FY 2001	1,780,400	308,600	167,300	250,900	24,200	298,700	153,000	57,300	209,300	179,200	131,900
TRAVEL											
FY 1999	47,800	8,800	4,300	6,600	600	7,500	3,300	1,600	4,700	3,700	6,700
FY 2000	51,700	8,800	5,300	6,100	700	7,300	3,500	1,400	4,400	3,500	10,700
FY 2001	53,200	8,800	5,300	6,100	700	7,300	3,500	1,400	4,500	3,800	11,800
RESEARCH OPERATIONS SUPPORT											
FY 1999	463,200	40,600	91,600	53,400	20,700	52,500	28,900	5,500	24,900	27,100	118,000
FY 2000	482,824	39,900	90,000	52,754	22,100	56,600	28,929	4,423	19,994	24,700	143,424
FY 2001	457,000	44,500	75,500	53,500	18,400	61,700	30,300	3,000	26,600	22,600	120,900
TOTAL											
FY 1999	2,109,600	334,600	246,300	287,800	41,300	334,000	170,900	56,700	214,400	194,000	229,600
FY 2000	2,217,624	340,100	255,300	294,954	45,400	349,200	174,029	58,923	222,894	198,600	278,224
FY 2001	2,290,600	361,900	248,100	310,500	43,300	367,700	186,800	61,700	240,400	205,600	264,600

SUMMARY OF BUDGET PLAN BY INSTALLATION
(Thousands of Dollars)

	FY 1999	FY 2000	FY 2001
JOHNSON SPACE CENTER	$334,600	$340,100	$361,900
KENNEDY SPACE CENTER	$246,300	$255,300	$248,100
MARSHALL SPACE FLIGHT CENTER	$287,800	$294,954	$310,500
STENNIS SPACE CENTER	$41,300	$45,400	$43,300
AMES RESEARCH CENTER	$170,900	$174,029	$186,800
DRYDEN FLIGHT RESEARCH CENTER	$56,700	$58,923	$61,700
LANGLEY RESEARCH CENTER	$214,400	$222,894	$240,400
GLENN RESEARCH CENTER	$194,000	$198,600	$205,600
GODDARD SPACE FLIGHT CENTER	$334,000	$349,200	$367,700
HEADQUARTERS	$229,600	$278,224	$264,600
AGENCY TOTAL	$2,109,600	$2,217,624	$2,290,600

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY INSTALLATION

	FY 1999	FY 2000	FY 2001
Johnson Space Center	3,040	2,926	3,030
Kennedy Space Center	1,759	1,806	1,825
Marshall Space Flight Center	2,653	2,651	2,758
Stennis Space Center	252	272	280
Goddard Space Flight Center	3,263	3,282	3,282
Ames Research Center	1,460	1,457	1,486
Dryden Flight Research Center	597	634	634
Langley Research Center	2,328	2,382	2,387
Glenn Research Center	1,991	1,983	1,972
Headquarters	935	1,020	1,087
Total, full-time equivalents	**18,278**	**18,413**	**18,741**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**1,846**	**1,751**	**1,708**
Major Development Programs	363	285	232
Payloads Program	73	43	39
Explorer Program	225	208	181
Mars Surveyor Program	41	49	47
Discovery Program	15	14	17
Operating Missions	79	83	81
Research and Technology	1,050	1,069	1,111
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**5,364**	**5,294**	**5,627**
International Space Station	2,136	2,385	2,328
Space Operations (SOMO)	358	281	271
Space Flight Operations (Space Shuttle)	1,819	1,754	2,017
Payload & ELV	274	304	353
Life & Microgravity Sciences & Apps	420	481	498
Investment - HEDS	357	89	160
EARTH SCIENCE	**1,365**	**1,382**	**1,419**
Earth Observing System Program	512	593	689
Earth Probes Program	110	121	73
Operating Missions	34	32	30
Research and Technology	622	554	546
ES Reimbursable Activities	87	82	81
AERO-SPACE TECHNOLOGY	**4,227**	**4,227**	**4,414**
Aero-space Focused Programs	945	1,218	1,408
High Speed Research Program	273	3	1
Advanced Subsonics Tech Program	298	51	94
Aero-Space Base	2,405	2,672	2,630
Commercial Technology Program	215	191	190
Investment - AST	91	92	91
PROGRAM OPERATIONS	**5,476**	**5,759**	**5,573**
Corporate Programs	210	240	232
Corporate Operations	1,052	1,140	1,207
Center Operations	4,214	4,379	4,134
Total full-time equivalents	**18,278**	**18,413**	**18,741**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
JOHNSON SPACE CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**30**	**40**	**36**
Major Development Programs	0	0	0
Mars Surveyor Program	0	6	3
Discovery Program	2	3	3
Operating Missions	1	1	1
Research and Technology	27	30	29
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**2,112**	**1,994**	**2,080**
International Space Station	883	1,013	1,021
Space Operations (SOMO)	31	29	30
Space Flight Operations (Space Shuttle)	841	834	905
Life & Microgravity Sciences & Apps	98	87	89
Investment - HEDS	259	31	35
AERO-SPACE TECHNOLOGY	**23**	**25**	**24**
Aero-Space Focused Programs	2	1	0
Aero-Space Base	5	8	8
Commercial Technology Program	16	16	16
PROGRAM OPERATIONS	**875**	**867**	**890**
Corporate Programs	15	18	24
Corporate Operations	9	9	9
Center Operations	851	840	857
Total full-time equivalents	**3,040**	**2,926**	**3,030**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
KENNEDY SPACE CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**1,246**	**1,173**	**1,304**
International Space Station	346	321	328
Space Flight Operations (Space Shuttle)	630	563	657
Payload & ELV Support	206	236	269
Life & Microgravity Sciences & Apps	16	15	16
Investment – HEDS	48	38	34
AERO-SPACE TECHNOLOGY	**33**	**48**	**37**
Aero-Space Focused Programs	15	30	21
Commercial Technology Program	18	18	16
PROGRAM OPERATIONS	**480**	**585**	**484**
Corporate Programs	29	31	31
Center Operations	451	554	453
Total full-time equivalents	**1,759**	**1,806**	**1,825**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

MARSHALL SPACE FLIGHT CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**265**	**168**	**149**
Major Development Programs	96	10	7
Operating Missions	4	2	2
Research and Technology	165	156	140
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**1,109**	**1,224**	**1,308**
International Space Station	612	736	702
Space Operations (SOMO)	12	11	11
Space Flight Operations (Space Shuttle)	325	337	435
Payload & ELV	11	11	26
Life & Microgravity Sciences & Apps	102	112	112
Investment - HEDS	47	17	22
EARTH SCIENCE	**98**	**46**	**46**
Earth Observing System Program	6	4	4
Operating Missions	1	0	0
Research and Technology	80	35	35
ES Reimbursable Activities	11	7	7
AERO-SPACE TECHNOLOGY	**526**	**603**	**664**
Aero-Space Focused Programs	371	216	244
Advanced Subsonics Tech Program	0	49	92
Aero-Space Base	112	307	297
Commercial Technology Program	**43**	**31**	**31**
PROGRAM OPERATIONS	**655**	**610**	**591**
Corporate Programs	44	44	26
Corporate Operations	**34**	**34**	**33**
Center Operations	577	532	532
Total full-time equivalents	**2,653**	**2,651**	**2,758**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

STENNIS SPACE CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**15**	**15**	**81**
Space Flight Operations (Space Shuttle)	12	12	12
Investment - HEDS	3	3	69
EARTH SCIENCE	**26**	**26**	**26**
Research and Technology	26	26	26
AERO-SPACE TECHNOLOGY	**44**	**22**	**35**
Aero-Space Focused Programs	33	16	20
Advanced Subsonics Tech Program	0	0	0
Aero-Space Base	8	3	12
Commercial Technology Program	3	3	3
PROGRAM OPERATIONS	**167**	**209**	**138**
Corporate Programs	16	26	33
Center Operations	151	183	105
Total full-time equivalents	**252**	**272**	**280**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GODDARD SPACE FLIGHT CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**1,010**	**1,013**	**990**
Major Development Programs	193	201	167
Payloads Program	73	43	39
Explorer Program	221	204	177
Mars Surveyor Program	4	3	2
Discovery Program	4	4	6
Operating Missions	69	75	78
Research and Technology	446	483	521
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**307**	**223**	**214**
Space Operations (SOMO)	257	175	166
Space Flight Operations (Space Shuttle)	4	2	2
Payload & ELV	46	46	46
EARTH SCIENCE	**882**	**940**	**964**
Earth Observing System Program	430	513	607
Earth Probes Program	97	108	58
Operating Missions	32	31	29
Research and Technology	247	213	196
ES Reimbursable Activities	76	75	74
AERO-SPACE TECHNOLOGY	**45**	**48**	**46**
High Speed Research Program	2	3	1
Advanced Subsonics Tech Program	4	2	2
Commercial Technology Program	39	43	43
PROGRAM OPERATIONS	**1,019**	**1,058**	**1,068**
Corporate Programs	33	45	40
Corporate Operations	69	69	70
Center Operations	917	944	958
Total full-time equivalents	**3,263**	**3,282**	**3,282**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
AMES RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**211**	**226**	**241**
Major Development Programs	59	59	55
Mars Surveyor Program	2	5	5
Discovery Program	2	0	0
Research and Technology	148	162	181
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**110**	**122**	**122**
International Space Station	53	65	68
Space Flight Operations (Space Shuttle)	2	2	2
Life & Microgravity Sciences & Apps	55	55	52
EARTH SCIENCE	**40**	**51**	**61**
Earth Observing System Program	1	1	2
Research and Technology	39	50	59
AERO-SPACE TECHNOLOGY	**714**	**671**	**675**
Aero-Space Focused Programs	198	240	235
High Speed Research Program	26	0	0
Advanced Subsonics Tech Program	48	0	0
Aero-Space Base	401	392	401
Commercial Technology Program	17	15	15
Investment - AST	24	24	24
PROGRAM OPERATIONS	**385**	**387**	**387**
Corporate Programs	15	15	16
Corporate Operations	5	8	8
Center Operations	365	364	363
Total full-time equivalents	**1,460**	**1,457**	**1,486**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
DRYDEN FLIGHT RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**51**	**53**	**49**
International Space Station	25	29	25
Space Operations (SOMO)	21	20	20
Space Flight Operations (Space Shuttle)	5	4	4
EARTH SCIENCE	**27**	**27**	**27**
Research and Technology	27	27	27
AERO-SPACE TECHNOLOGY	**399**	**396**	**401**
Aero-Space Focused Programs	59	71	76
Aero-Space Base	326	313	313
Commercial Technology Program	5	3	3
Investment - AST	9	9	9
PROGRAM OPERATIONS	**120**	**158**	**157**
Corporate Programs	13	17	10
Center Operations	107	141	147
Total full-time equivalents	**597**	**634**	**634**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

LANGLEY RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**119**	**119**	**114**
Major Development Programs	15	15	3
Explorer Program	4	4	4
Mars Surveyor Program	35	35	37
Discovery Program	7	7	8
Operating Missions	5	5	0
Research and Technology	53	53	62
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**41**	**41**	**48**
International Space Station	30	30	36
Payload & ELV	11	11	12
EARTH SCIENCE	**292**	**292**	**295**
Earth Observing System Program	75	75	76
Earth Probes Program	13	13	15
Operating Missions	1	1	1
Research and Technology	203	203	203
AERO-SPACE TECHNOLOGY	**1,418**	**1,440**	**1,535**
Aero-Space Focused Programs	162	378	488
High Speed Research Program	105	0	0
Advanced Subsonics Tech Program	115	0	0
Aero-Space Base	958	984	968
Commercial Technology Program	42	42	43
Investment - AST	36	36	36
PROGRAM OPERATIONS	**458**	**490**	**395**
Corporate Programs	24	24	32
Center Operations	434	466	363
Total full-time equivalents	**2,328**	**2,382**	**2,387**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GLENN RESEARCH CENTER

	FY 1999	FY 2000	FY 2001
SPACE SCIENCE	**211**	**185**	**178**
Research and Technology	211	185	178
HUMAN EXPLOR. & DEVELOPMENT OF SPACE	**373**	**449**	**421**
International Space Station	187	191	148
Space Operations (SOMO)	37	46	44
Life & Microgravity Sciences & Apps	149	212	229
AERO-SPACE TECHNOLOGY	**1,025**	**974**	**997**
Aero-Space Focused Programs	105	266	324
High Speed Research Program	140	0	0
Advanced Subsonics Tech Program	131	0	0
Aero-Space Base	595	665	631
Commercial Technology Program	32	20	20
Investment - AST	22	23	22
PROGRAM OPERATIONS	**382**	**375**	**376**
Corporate Programs	21	20	20
Center Operations	361	355	356
Total full-time equivalents	**1,991**	**1,983**	**1,972**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

NASA HEADQUARTERS

	FY 1999	FY 2000	FY 2001
PROGRAM OPERATIONS	**935**	**1,020**	**1,087**
Corporate Operations	935	1,020	1,087
Total full-time equivalents	**935**	**1,020**	**1,087**

DETAIL OF PERMANENT POSITIONS

	FY 1999	FY 2000	FY 2001
Executive level II	1	1	1
Executive level IV	2	2	2
Subtotal	**3**	**3**	**3**
ES-6	36	50	50
ES-5	70	109	109
ES-4	121	146	146
ES-3	52	70	70
ES-2	54	62	62
ES-1	66	68	68
Subtotal	**399**	**505**	**505**
CA	1	1	1
SL/ST	56	56	56
GS-15	2381	2392	2405
GS-14	3535	3567	3607
GS-13	5834	5866	5906
GS-12	1785	1817	1857
GS-11	1205	1205	1205
GS-10	244	244	244
GS-9	489	596	695
GS-8	261	261	261
GS-7	589	696	794
GS-6	490	490	490
GS-5	104	104	104
GS-4	20	20	20
GS-3	5	5	5
GS-2	2	2	2
Subtotal	**17,001**	**17,322**	**17,652**
Special ungraded positions established by NASA Administrator	26	26	26
Ungraded positions	309	309	309
Total permanent positions	**17,738**	**18,165**	**18,495**
Unfilled positions, EOY	0	0	0
Total, permanent employment, EOY	**17,738**	**18,165**	**18,495**

PERSONNEL SUMMARY

	FY 1999	FY 2000	FY 2001
Average GS/GM grade	12.53	12.48	12.43
Average ES salary	$121,218	$126,430	$131,942
Average GS/GM salary	$67,079	$70,299	$73,392
Average salary of special ungraded positions established by NASA Administrator	$88,071	$91,594	$95,624
Average salary of ungraded positions	$46,522	$48,383	$50,512

CENTER LOCATIONS AND CAPITAL INVESTMENT

JOHNSON SPACE CENTER - The Lyndon B. Johnson Space Center is located 20 miles southeast of Houston, Texas. NASA owns 1,581 acres of land at the Houston site and uses another 60,552 at the White Sands Test Facility, Las Cruces, New Mexico. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $2,339,529 as of September 30, 1999.

KENNEDY SPACE CENTER - The Kennedy Space Center is located 50 miles east of Orlando, Florida. NASA owns 82,943 acres and uses launch facilities at Cape Canaveral Air Station and Vandenberg Air Force Base. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,799,479 as of September 30, 1999.

MARSHALL SPACE FLIGHT CENTER - The Marshall Space Flight Center is located within the U.S. Army's Redstone Arsenal at Huntsville, Alabama. MSFC also manages operation at the Michoud Assembly 15 miles east of New Orleans, Louisiana and the Slidell Computer Complex in Slidell, Louisiana. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,935,733 as of September 30, 1999.

STENNIS SPACE CENTER - The Stennis Space Center is located approximately 50 miles northeast of New Orleans, Louisiana. NASA owns 20,663 acres and has easements covering an additional 118,284 acres. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $473,822 as of September 30, 1999.

GODDARD SPACE FLIGHT CENTER - The Goddard Space Flight Center is located 15 miles northeast of Washington, D.C. at Greenbelt, Maryland. NASA owns 1,121 acres at this location and an additional 6,176 acres at the Wallops Flight Facility in Wallops Island, Virginia. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $2,040,240 as of September 30, 1999.

AMES RESEARCH CENTER - The Ames Research Center is located south of San Francisco on Moffett Field, California. NASA owns 447.5 acres at the Moffett Field location. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $885,458 as of September 30, 1999.

DRYDEN FLIGHT RESEARCH CENTER - The Dryden Flight Research Center is 65 air miles northeast of Los Angeles. Dryden is located at the north end of Edwards Air Force Base on 838 acres of land under a permit from the Air Force. The total capital investment at Dryden, including fixed assets in progress and contractor-held facilities at various locations, as of September 30, 1999 was $391,893.

LANGLEY RESEARCH CENTER - The Langley Research Center is adjacent to Langley Air Force Base which is located between Williamsburg and Norfolk at Hampton, Virginia. NASA owns 788 acres and has access to 3,276 acres. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets was $1,002,192 as of September 30, 1999.

LEWIS RESEARCH CENTER - The Lewis Research Center occupies two sites; the main site is in Cleveland, Ohio, adjacent to Cleveland-Hopkins Airport; the second site is the Plum Brook Station located south of Sandusky, Ohio, and 50 miles west of Cleveland. NASA owns 6,805 acres and leases an additional 14 acres at the Cleveland location. The total capital investment including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $647,237 as September 30, 1999.

NASA HEADQUARTERS - NASA Headquarters is located at Two Independence Square, 300 E St. SW, Washington, D.C. and occupies other buildings in the District of Columbia, Maryland, and Virginia.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001

SUMMARY OF CONSULTING SERVICES ESTIMATES

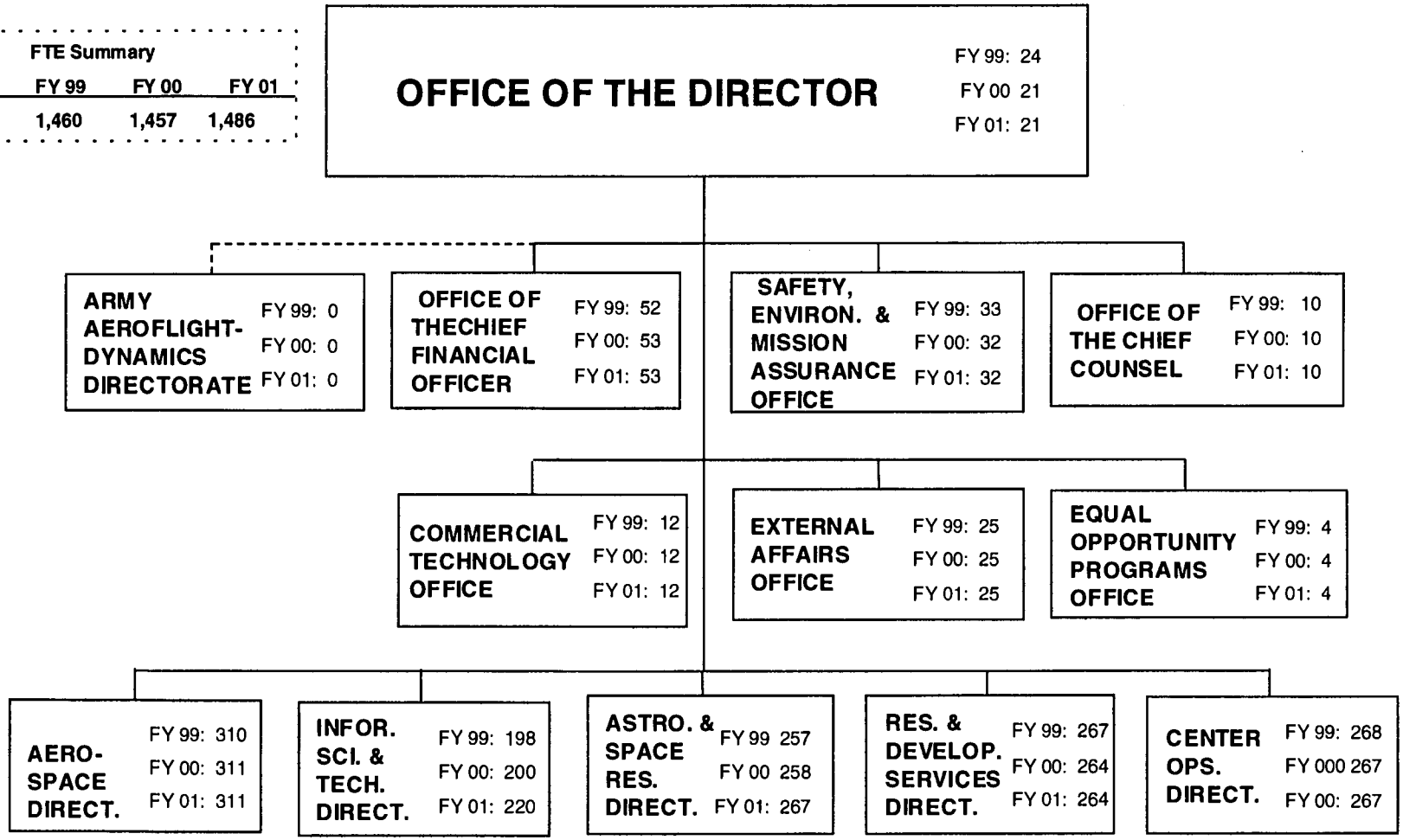
NASA uses paid experts and consultants to provide advice and expert input in addition to or beyond that available from its in-house civil service workforce. Management controls are established which assure that before entering into a consultant services arrangement with an individual that there is ample justification presented and the action is approved at top management levels.

NASA hires experts and consultants to provide expert advice and input on the selection of experiments for future space missions. The use of these experts and consultants, in addition to NASA civil service personnel, provides the agency with an independent view that assures the selection of experiments likely to have the greatest scientific merit. Other individuals are employed to provide independent looks at technical and functional problems in order to give top management the widest possible range of views before making major decisions.

	FY 1999	FY 2000	FY 2001
Number of Experts and Consultants	283	290	290
Annual FTE Usage	4	4	4
Average Annual Salary	$63,000	$66,100	$69,000
Total Salary and Benefits Costs	$273,420	$286,818	$297,430
Travel Costs	$595,000	$618,800	$643,500
Total Costs	$868,420	$905,618	$940,930

AMES RESEARCH CENTER
(ARC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	1,460	1,457	1,486



DRYDEN FLIGHT RESEARCH CENTER
(DFRC)

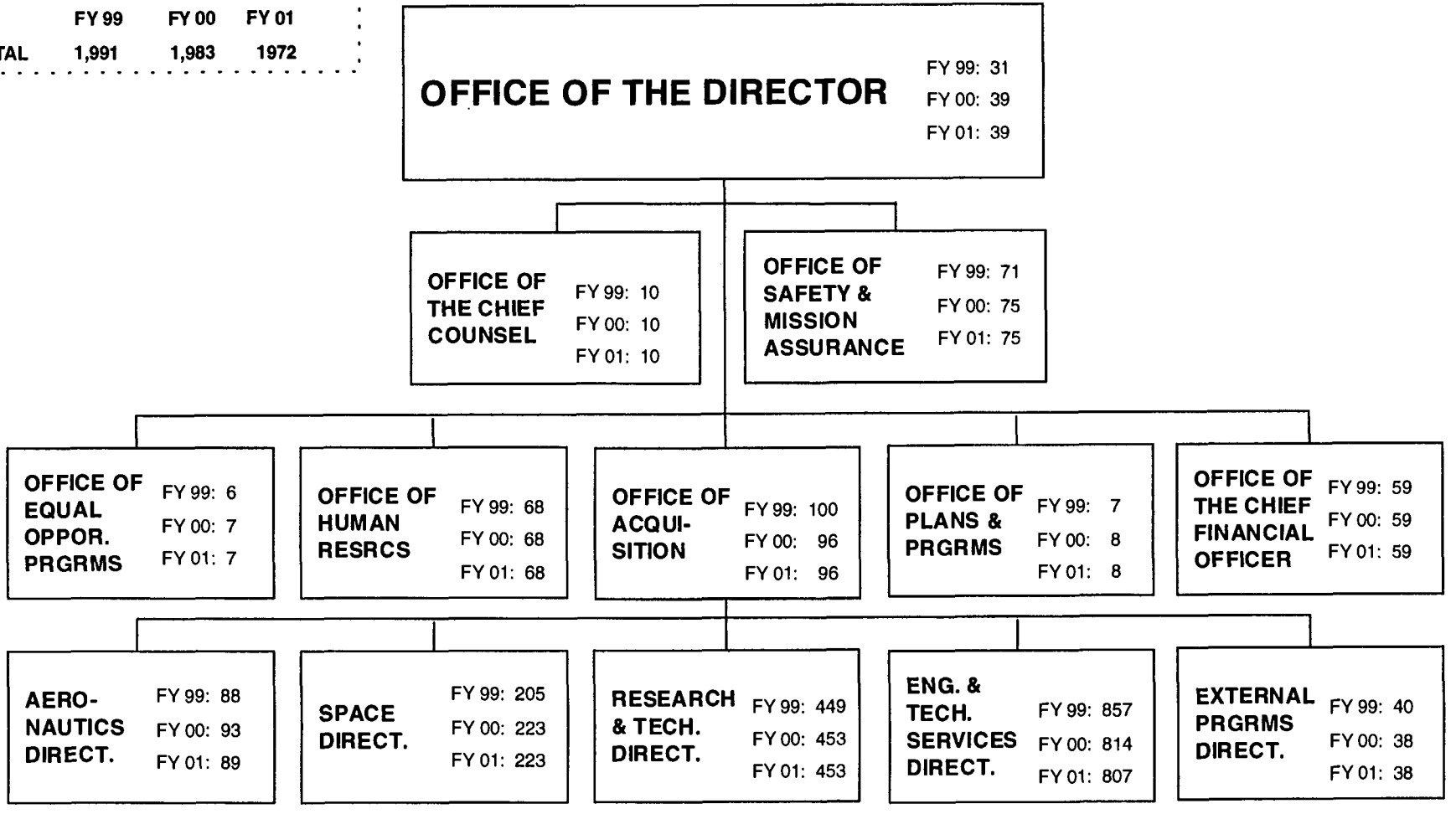
FTE Summary	FY 99	FY 00	FY01
TOTAL	597	634	634

OFFICE OF THE DIRECTOR
FY 99: 19
FY 00: 21
FY 01: 21

- **EQUAL OPPORTUNITY OFFICE** — FY 99: 2; FY 00: 3; FY 01: 3
- **HUMAN RESOURCES MGMT & DEVEL. OFFICE** — FY 99: 25; FY 00: 26; FY01: 26
- **PUBLIC AFFAIRS, COMM., & ED. OFFICE** — FY 99: 12; FY 00: 13; FY 01: 13
- **SECURITY OFFICE** — FY 99: 5; FY 00: 5; FY 01: 5
- **ACQUISITION MGMT OFFICE** — FY 99: 20; FY 00: 23; FY 01: 23
- **OFFICE OF SAFETY & MISSION ASSURANCE** — FY 99: 17; FY 00: 18; FY 01: 18
- **OFFICE OF THE CHIEF FINANCIAL OFFICER** — FY 99: 36; FY 00: 36; FY 01: 36
- **OFFICE OF THE CHIEF COUNSEL** — FY 99: 4; FY 00: 4; FY 01: 4
- **AIR-BORNE SCIENCES DIRECT.** — FY 99: 13; FY 00: 15; FY 01: 15
- **RES. FACIL. DIRECT.** — FY 99: 121; FY 00: 131; FY 01: 131
- **RES. ENG. DIRECT.** — FY 99: 127; FY 00: 146; FY 01: 146
- **FLIGHT OPS. DIRECT.** — FY 99: 168; FY 00: 164; FY 01: 164
- **AERO-SPACE PROJECTS DIRECT.** — FY 99: 27; FY 00: 29; FY 01: 29

JOHN H. GLENN RESEARCH CENTER at LEWIS FIELD
(GRC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	1,991	1,983	1972



GODDARD SPACE FLIGHT CENTER
(GSFC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	3,263	3,282	3,282

Office Of The Director — FTE: FY 99: 22; FY 00: 22; FY 01: 22

- **Office of Equal Opportunity Programs** — FTE: FY 99: 7; FY 00: 8; FY 01: 8
- **Office Of Public Affairs** — FTE: FY 99: 32; FY 00: 30; FY 01: 30
- **Office Of The Chief Counsel** — FTE: FY 99: 8; FY 00: 9; FY 01: 9
- **Office Of University Programs** — FTE: FY 99: 3; FY 00: 3; FY 01: 3
- **Inspector General Field Office**
- **Office Of Human Resources** — FTE: FY 99: 64; FY 00: 65; FY 01: 65
- **Office Of The Chief Financial Officer** — FTE: FY 99: 101; FY 00: 102; FY 01: 102
- **Office Of Sys. Safety & Mission Assurance** — FTE: FY 99: 61; FY 00: 62; FY 01: 62
- **Mgmt. Operations Direct.** — FTE: FY 99: 579; FY 00: 584; FY 01: 584
- **Applied Eng. & Tech. Direct.** — FTE: FY 99: 1164; FY 00: 1171; FY 01: 1171
- **Sys. Tech. & Adv. Concepts Direct.** — FTE: FY 99: 219; FY 00: 220; FY 01: 220
- **Flight Programs & Projects Direct.** — FTE: FY 99: 333; FY 00: 333; FY 01: 333
- **Space Sciences Direct.** — FTE: FY 99: 238; FY 00: 239; FY 01: 239
- **Suborbital & Special Orb. Projects Direct.** — FTE: FY 99: 94; FY 00: 95; FY 01: 95
- **Earth Sciences Direct.** — FTE: FY 99: 338; FY 00: 339; FY 01: 339

HEADQUARTERS

FTE Summary	FY 99	FY 00	FY 01
TOTAL	935	1020	1087

OFFICE OF THE ADMINISTRATOR — FTE: FY 99: 32; FY 00: 36; FY 01: 40

- **INSPECTOR GENERAL (W)** — FTE: FY 99: 191; FY 00: 210; FY 01: 213
- AEROSPACE SAFETY ADVISORY PANEL
- NASA ADVISORY COUNCIL

STAFF OFFICES

- **CHIEF FINANCIAL OFFICER (B)** — FTE: FY 99: 50; FY 00: 54; FY 01: 58
- **GENERAL COUNSEL (G)** — FTE: FY 99: 37; FY 00: 37; FY 01: 37
- **EQUAL OPPORTUNITY PROGRAMS (E)** — FTE: FY 99: 29; FY 00: 31; FY 01: 31
- **EXTERNAL RELATIONS (I)** — FTE: FY 99: 56; FY 00: 56; FY 01: 56
- **LEGISLATIVE AFFAIRS (L)** — FTE: FY 99: 28; FY 00: 28; FY 01: 28
- **HUMAN RESOURCES AND EDUCATION (F)** — FTE: FY 99: 54; FY 00: 57; FY 01: 59
- **PROCUREMENT (H) (Includes Agency Procurement Interns)** — FTE: FY 99: 47; FY 00: 66; FY 01: 77
- **PUBLIC AFFAIRS (P)** — FTE: FY 99: 49; FY 00: 49; FY 01: 49
- **POLICY & PLANS (Z)** — FTE: FY 99: 18; FY 00: 18; FY 01: 18
- **MANAGEMENT SYSTEMS AND FACILITIES (J)** — FTE: FY 99: 58; FY 00: 66; FY 01: 70
- **SAFETY AND MISSION ASSUR. (Q)** — FTE: FY 99: 38; FY 00: 41; FY 01: 43
- **HEADQUARTERS OPERATIONS (C) (Includes Students, Temps for all HQ)** — FTE: FY 99: 99; FY 00: 115; FY 01: 121
- **SMALL AND DISADVANTAGED BUSINESS UTILIZATION (K)** — FTE: FY 99: 7; FY 00: 7; FY 01: 7

PROGRAM OFFICES

- **EARTH SCIENCE (Y)*** — FTE: FY 99: 55; FY 00: 64; FY 01: 75
- **SPACE FLIGHT (M)** — FTE: FY 99: 72; FY 00: 75; FY 01: 86
- **LIFE & MICROGRAVITY SCIENCES & APPLICATIONS (U)** — FTE: FY 99: 50; FY 00: 53; FY 01: 53
- **SPACE SCIENCE (S) (Includes NMO @ JPL)** — FTE: FY 99: 92; FY 00: 99; FY 01: 102
- **AERO-SPACE TECHNOLOGY (R)** — FTE: FY 99: 64; FY 00: 68; FY 01: 77

LYNDON B. JOHNSON SPACE CENTER
(JSC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	3,040	2,926	3,030

OFFICE OF THE DIRECTOR
FTE:
FY 99: 15
FY 00: 19
FY 01: 19

HUMAN RESRCS OFFICE
FTE:
FY 99: 52
FY 00: 50
FY 01: 51

EQUAL OPPOR. PRGRMS OFFICE
FTE:
FY 99: 6
FY 00: 6
FY 01: 6

LEGAL OFFICE
FTE:
FY 99: 12
FY 00: 12
FY 01: 12

PUBLIC AFFAIRS OFFICE
FTE:
FY 99: 35
FY 00: 35
FY 01: 35

ISO 9000 OFFICE
FTE:
FY 99: 7
FY 00: 7
FY 01: 7

OFFICE OF THE CHIEF INFOR. OFFICER
FTE:
FY 99: 17
FY 00: 17
FY 01: 17

SAFETY, RELBLTY & QUALITY ASSURANCE OFFICE
FTE:
FY 99: 135
FY 00: 130
FY 01: 134

OFFICE OF THE CHIEF FINANCIAL OFFICER
FTE:
FY 99: 155
FY 00: 150
FY 01: 153

TECH. TRANSFER & COMM. OFFICE
FTE:
FY 99: 14
FY 00: 14
FY 01: 14

SPACE STATION PRGRM OFFICE
FTE:
FY 99: 274
FY 00: 267
FY 01: 277

SPACE SHUTTLE PRGRM OFFICE
FTE:
FY 99: 138
FY 00: 135
FY 01: 145

SPACE OPS MGMT OFFICE
FTE:
FY 99: 21
FY 00: 21
FY 01: 21

EVA PROJECT OFFICE
FTE:
FY 99: 26
FY 00: 26
FY 01: 26

MISSION OPERATIONS DIRECTORATE
FTE:
FY 99: 468
FY 00: 444
FY 01: 462

BUSINESS MANAGEMENT DIRECTORATE
FTE:
FY 99: 168
FY 00: 164
FY 01: 166

INFORMATION SYSTEMS DIRECTORATE
FTE:
FY 99: 93
FY 00: 91
FY 01: 92

CENTER OPERATIONS DIRECTORATE
FTE:
FY 99: 134
FY 00: 131
FY 01: 133

ENGINEERING DIRECTORATE
FTE:
FY 99: 841
FY 00: 791
FY 01: 835

SPACE & LIFE SCIENCES DIRECTORATE
FTE:
FY 99: 197
FY 00: 192
FY 01: 194

FLIGHT CREW OPERATIONS DIRECTORATE
FTE:
FY 99: 183
FY 00: 178
FY 01: 183

WHITE SANDS TEST FACILITY
FTE:
FY 99: 49
FY 00: 46
FY 01: 48

JOHN F. KENNEDY SPACE CENTER
(KSC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	1,759	1,806	1,825

OFFICE OF THE DIRECTOR
FTE:
FY 99: 30
FY 00: 30
FY 01: 28

BUS. INNOV. GROUP
FTE:
FY 99: 9
FY 00: 8
FY 01: 8

CHIEF COUNSEL OFFICE
FTE:
FY 99: 11
FY 00: 10
FY 01: 10

EQUAL OPPOR. OFFICE
FTE:
FY 99: 5
FY 00: 4
FY 01: 5

OFFICE OF THE CHIEF INFO. OFFICER
FTE:
FY 99: 4
FY 00: 3
FY 01: 3

JOINT PERF. MGMT OFFICE
FTE:
FY 99: 16
FY 00: 15
FY 01: 12

PUBLIC AFFAIRS OFFICE
FTE:
FY 99: 32
FY 00: 30
FY 01: 30

ADMIN. OFFICE
FTE:
FY 99: 131
FY 00: 120
FY 01: 119

PROCURE-MENT OFFICE
FTE:
FY 99: 67
FY 00: 69
FY 01: 70

OFFICE OF THE CHIEF FINANCIAL OFFICER
FTE:
FY 99: 74
FY 00: 75
FY 01: 85

BIO-MEDICAL OFFICE
FTE:
FY 99: 44
FY 00: 32
FY 01: 32

ELV & PAYLOAD CARRIERS PRGRM OFC
FTE:
FY 99: 168
FY 00: 173
FY 01: 181

SPACE STATION HARDWARE INTEG. OFC
FTE:
FY 99: 67
FY 00: 76
FY 01: 77

CHECKOUT & LAUNCH CONTRL SYS OFC
FTE:
FY 99: 18
FY 00: 18
FY 01: 15

SHUTTLE PROCESSING DIRECT.
FTE:
FY 99: 260
FY 00: 287
FY 01: 289

LOGISTICS OPS DIRECT.
FTE:
FY 99: 112
FY 00: 115
FY 01: 112

SAFETY & MISSION ASSUR. DIRECT.
FTE:
FY 99: 201
FY 00: 207
FY 01: 210

ENG. DEVEL. DIRECT.
FTE:
FY 99: 198
FY 00: 200
FY 01: 201

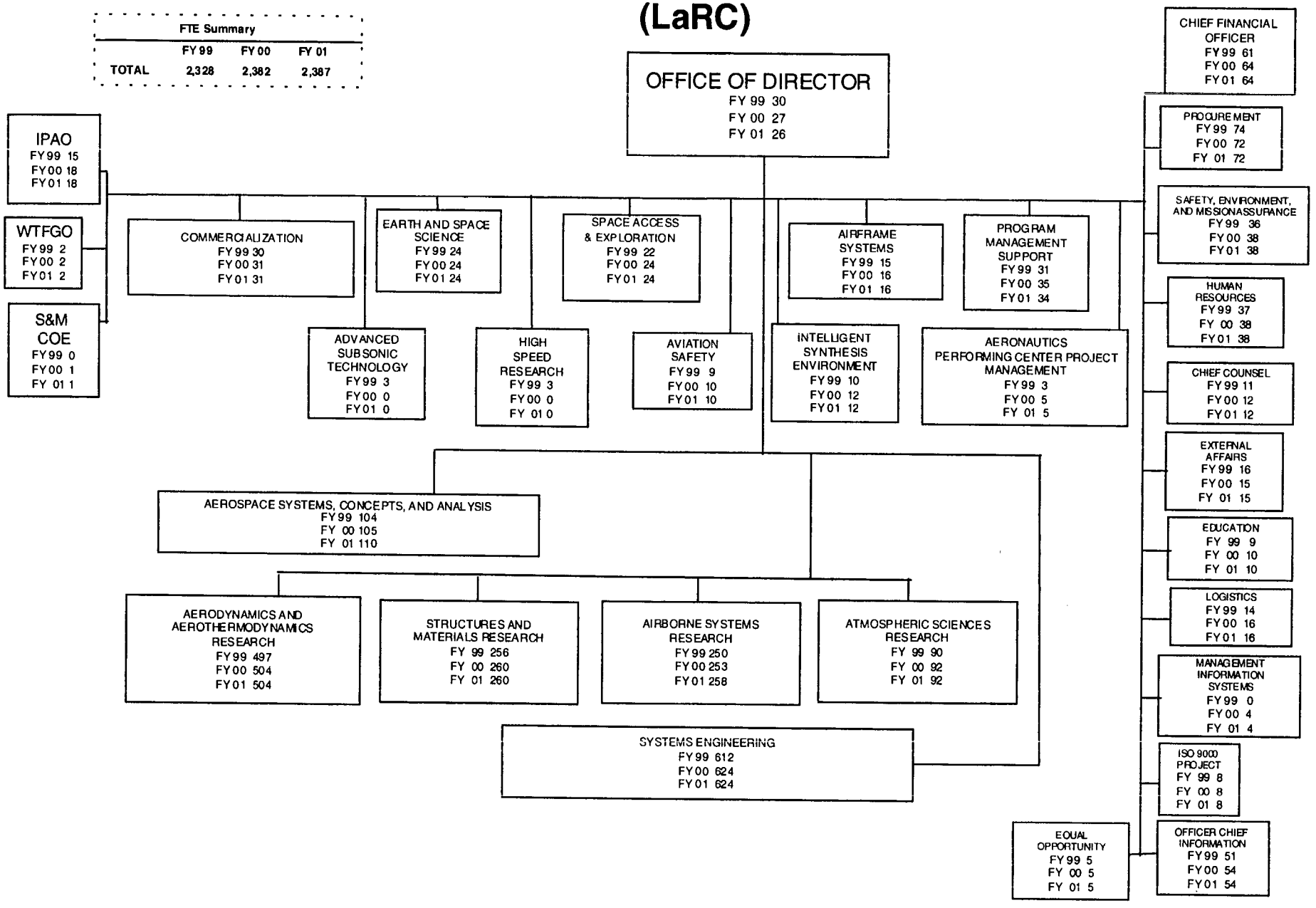
INSTAL-LATION OPS. DIRECT.
FTE:
FY 99: 130
FY 00: 131
FY 01: 131

SPACE STATION & SHUTTLE PAYLOADS DIRECT.
FTE:
FY 99: 182
FY 00: 203
FY 01: 207

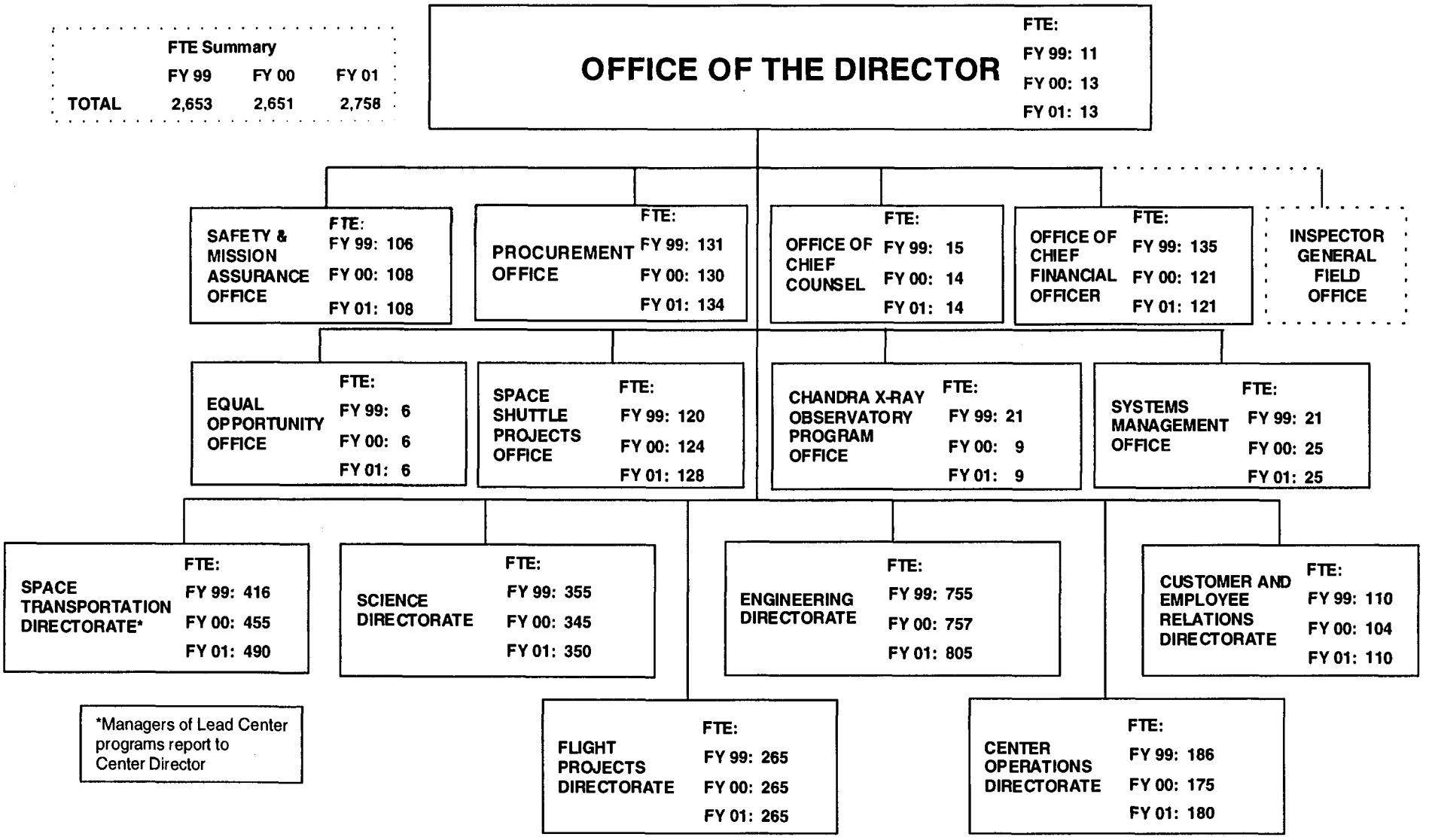
Note: KSC is undergoing a Center reorganization. Distribution of FTE for FY 00 and FY 01 does not indicate expected changes.

LANGLEY RESEARCH CENTER
(LaRC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	2,328	2,382	2,387



MARSHALL SPACE FLIGHT CENTER
(MSFC)



JOHN C. STENNIS SPACE CENTER
(SSC)

FTE Summary	FY 99	FY 00	FY 01
TOTAL	252	272	280

OFFICE OF THE DIRECTOR — FTE: FY 99: 5; FY 00: 6; FY 01: 6

- **EQUAL OPPORTUNITY OFFICE** — FTE: FY 99: 2; FY 00: 1; FY 01: 1
- **EDUCATION & UNIVERSITY AFFAIRS OFFICE** — FTE: FY 99: 5; FY 00: 5; FY 01: 5
- **OFFICE OF THE CHIEF COUNSEL** — FTE: FY 99: 4; FY 00: 4; FY 01: 4
- **PUBLIC AFFAIRS OFFICE** — FTE: FY 99: 6; FY 00: 5; FY 01: 5
- **HUMAN RESRCS & MGMT SERVICES OFFICE** — FTE: FY 99: 12; FY 00: 11; FY 01: 11
- **OFFICE OF THE CHIEF FINANCIAL OFFICER** — FTE: FY 99: 26; FY 00: 29; FY 01: 29
- **COMMER. REMOTE SENSING PROGRAM OFFICE** — FTE: FY 99: 15; FY 00: 19; FY 01: 19
- **EARTH SYSTEM SCIENCE OFFICE** — FTE: FY 99: 11; FY 00: 10; FY 01: 10
- **PROCURE-MENT OFFICE** — FTE: FY 99: 18; FY 00: 23; FY 01: 24
- **SAFETY& MISSION ASSURANCE OFFICE** — FTE: FY 99: 14; FY 00: 16; FY 01: 16
- **TECHN. TRANSFER OFFICE** — FTE: FY 99: 3; FY 00: 4; FY 01: 4
- **PROPULSION TEST DIRECT.** — FTE: FY 99: 84; FY 00: 89; FY 01: 96
- **CENTER OPERATIONS & SUPPORT DIRECT.** — FTE: FY 99: 47; FY 00: 50; FY 01: 50

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
TOTAL NASA

	DIRECT OBLIGATIONS	FY 1999	FY 2000	FY 2001
11	PERSONNEL COMPENSATION	1,266,737	1,339,800	1,419,800
12	PERSONNEL BENEFITS (CIVIL + PCS)	270,151	280,888	313,926
13	BENEFITS TO FORMER PERSONNEL	11,601	9,927	242
21	TRAVEL & TRANSP OF PERSONS	47,800	51,700	53,200
22	TRANSPORTATION OF THINGS	2,056	6,885	1,932
25	OTHER SERVICES	511,255	528,424	501,499
25	OTHER SERVICES (sal/bene + tvl)	48,055	45,600	44,499
25	OTHER SERVICES (ros)*	463,200	482,824	457,000
		2,109,600	2,217,624	2,290,600

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
JOHNSON SPACE CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	227,620	234,445	249,815
12	PERSONNEL BENEFITS (CIVIL + PCS)	47,153	47,345	53,444
13	BENEFITS TO FORMER PERSONNEL	3,536	4,323	0
21	TRAVEL & TRANSP OF PERSONS	8,800	8,800	8,800
22	TRANSPORTATION OF THINGS	342	1,000	205
25	OTHER SERVICES	47,149	44,187	49,636
25	OTHER SERVICES (sal/bene + tvl)	6,549	4,287	5,136
25	OTHER SERVICES (ros)*	40,600	39,900	44,500
		334,600	340,100	361,900

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
KENNEDY SPACE CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	115,384	125,872	133,031
12	PERSONNEL BENEFITS (CIVIL + PCS)	28,015	27,727	29,276
13	BENEFITS TO FORMER PERSONNEL	2,557	1,105	0
21	TRAVEL & TRANSP OF PERSONS	4,300	5,300	5,300
22	TRANSPORTATION OF THINGS	213	2,331	1,290
25	OTHER SERVICES	95,831	92,965	79,203
25	OTHER SERVICES (sal/bene + tvl)	4,231	2,965	3,703
25	OTHER SERVICES (ros)*	91,600	90,000	75,500
		246,300	255,300	248,100

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
MARSHALL SPACE FLIGHT CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	177,473	187,377	201,799
12	PERSONNEL BENEFITS (CIVIL + PCS)	39,817	40,616	45,096
13	BENEFITS TO FORMER PERSONNEL	5,135	4,257	0
21	TRAVEL & TRANSP OF PERSONS	6,600	6,100	6,100
22	TRANSPORTATION OF THINGS	373	330	71
25	OTHER SERVICES	58,402	56,274	57,434
25	OTHER SERVICES (sal/bene + tvl)	5,002	3,520	3,934
25	OTHER SERVICES (ros)*	53,400	52,754	53,500
		287,800	294,954	310,500

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
STENNIS SPACE CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	15,704	18,129	19,403
12	PERSONNEL BENEFITS (CIVIL + PCS)	3,917	4,224	4,558
13	BENEFITS TO FORMER PERSONNEL	0	0	0
21	TRAVEL & TRANSP OF PERSONS	600	700	700
22	TRANSPORTATION OF THINGS	106	55	10
25	OTHER SERVICES	20,973	22,292	18,629
25	OTHER SERVICES (sal/bene + tvl)	273	192	229
25	OTHER SERVICES (ros)*	20,700	22,100	18,400
		41,300	45,400	43,300

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
AMES RESEARCH CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	111,290	115,115	121,285
12	PERSONNEL BENEFITS (CIVIL + PCS)	24,157	23,463	28,657
13	BENEFITS TO FORMER PERSONNEL	108	0	0
21	TRAVEL & TRANSP OF PERSONS	3,300	3,500	3,500
22	TRANSPORTATION OF THINGS	0	180	41
25	OTHER SERVICES	32,045	31,771	33,317
25	OTHER SERVICES (sal/bene + tvl)	3,145	2,842	3,017
25	OTHER SERVICES (ros)*	28,900	28,929	30,300
		170,900	174,029	186,800

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
DRYDEN FLIGHT RESEARCH CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	39,388	42,237	45,344
12	PERSONNEL BENEFITS (CIVIL + PCS)	8,481	9,617	10,685
13	BENEFITS TO FORMER PERSONNEL	0	0	0
21	TRAVEL & TRANSP OF PERSONS	1,600	1,400	1,400
22	TRANSPORTATION OF THINGS	229	78	9
25	OTHER SERVICES	7,002	5,591	4,262
25	OTHER SERVICES (sal/bene + tvl)	1,502	1,168	1,262
25	OTHER SERVICES (ros)*	5,500	4,423	3,000
		56,700	58,923	61,700

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
GLENN RESEARCH CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	131,140	136,867	141,311
12	PERSONNEL BENEFITS (CIVIL + PCS)	27,801	29,873	33,659
13	BENEFITS TO FORMER PERSONNEL	23	0	0
21	TRAVEL & TRANSP OF PERSONS	3,700	3,500	3,800
22	TRANSPORTATION OF THINGS	60	0	0
25	OTHER SERVICES	31,276	28,360	26,830
25	OTHER SERVICES (sal/bene + tvl)	4,176	3,660	4,230
25	OTHER SERVICES (ros)*	27,100	24,700	22,600
		194,000	198,600	205,600

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
LANGLEY RESEARCH CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	149,632	161,174	165,984
12	PERSONNEL BENEFITS (CIVIL + PCS)	30,255	33,576	39,516
13	BENEFITS TO FORMER PERSONNEL	0	0	0
21	TRAVEL & TRANSP OF PERSONS	4,700	4,400	4,500
22	TRANSPORTATION OF THINGS	177	100	33
25	OTHER SERVICES	29,636	23,644	30,367
25	OTHER SERVICES (sal/bene + tvl)	4,736	3,650	3,767
25	OTHER SERVICES (ros)*	24,900	19,994	26,600
		214,400	222,894	240,400

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
GODDARD SPACE FLIGHT CENTER

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	222,422	231,823	243,411
12	PERSONNEL BENEFITS (CIVIL + PCS)	45,892	46,531	48,321
13	BENEFITS TO FORMER PERSONNEL	37	0	0
21	TRAVEL & TRANSP OF PERSONS	7,500	7,300	7,300
22	TRANSPORTATION OF THINGS	320	566	129
25	OTHER SERVICES	57,829	62,980	68,539
25	OTHER SERVICES (sal/bene + tvl)	5,329	6,380	6,839
25	OTHER SERVICES (ros)*	52,500	56,600	61,700
		334,000	349,200	367,700

*For this exercise, ROS funding has been included in OC25 only

OBJECT CLASSIFICATION (FY 2001 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
NASA HEADQUARTERS

		FY 1999	FY 2000	FY 2001
	DIRECT OBLIGATIONS			
11	PERSONNEL COMPENSATION	76,684	86,761	98,418
12	PERSONNEL BENEFITS (CIVIL + PCS)	14,663	17,916	20,714
13	BENEFITS TO FORMER PERSONNEL	205	242	242
21	TRAVEL & TRANSP OF PERSONS	6,700	10,700	11,800
22	TRANSPORTATION OF THINGS	236	2,245	144
25	OTHER SERVICES	131,112	160,360	132,282
25	OTHER SERVICES (sal/bene + tvl)	13,112	16,936	12,382
25	OTHER SERVICES (ros)*	118,000	143,424	120,900
		229,600	278,224	264,600

*For this exercise, ROS funding has been included in OC25 only

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

ADDITIONAL SPACE SHUTTLE RESEARCH MISSION

P.L. 106-74 includes a limitation stipulating that $40 million of the amount provided for Human Space Flight "shall be available to the space shuttle program only for preparations necessary to carry out a life and micro-gravity science mission, to be flown between STS-107 and December 2001." The amounts earmarked within the FY 2000 Shuttle budget ($40 million) and amounts available in FY 1999 appropriations for Life and Microgravity Sciences and Applications ($10 million) fall considerably short of the funds needed to conduct a science mission, which ranges from about $137-166 million. This would require that offsets of $87 -$116 million be identified in order to fund this mission. The President's FY 2001 budget request, as found in the supplemental appendix, proposes that rather than endure additional offsets to fund the additional science mission, the earmarked funds should be used for funding higher priority safety investments that will ensure the continued safe operation of the Space Shuttle. The amount of $20,200,000 is transferred from Space Shuttle Operations to Research and Program Management (R&PM) in the Mission Support appropriation in order to fund additional hiring of personnel in critical skill areas at human space flight centers (JSC, MSFC, KSC, and SSC). The remaining $19,800,000 is applied to high priority safety upgrades in the Space Shuttle program that will be fully in place in the Shuttle fleet by 2005.

INTEGRATED SPACE TRANSPORTATION PROGRAM FUNDING ESTIMATES THROUGH FY 2005

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Integrated Space Transportation Program	**524,599**	**582,700**	**730,000**	**1,216,500**	**1,511,600**	**1,863,800**	**1,897,500**
2nd Generation RLV Program	365,299	183,400	290,000	610,000	975,000	1,261,000	1,334,000
Systems Engineering & Requirements Definition			50,000	50,000	25,000	5,000	5,000
RLV Competition & Risk Reduction			95,000	287,000	556,000	816,000	604,000
NASA-Unique Systems			50,000	190,000	324,000	370,000	655,000
NASA-Unique System Elements			*50,000*	*95,000*	*134,000*	*140,000*	*405,000*
CRV Phase 2				*95,000*	*190,000*	*230,000*	*250,000*
Alternative Access			40,000	65,000	70,000	70,000	70,000
X-33	277,299	111,600					
On-Going Pathfinders (ends in FY 02)	71,500	71,800	55,000	18,000			
X-34	*35,500*	*40,500*	*17,900*	*13,800*			
X-37	*24,400*	*20,400*	*33,100*	*3,900*			
Other Pathfinder Projects	*11,600*	*10,900*	*4,000*	*300*			
Bantam	16,500						
Technology Base Program *	34,300	107,500	193,600	226,000	238,900	254,700	254,700
Future Space Launch Studies	30,000	30,000					
Shuttle Upgrades (HSF)	95,000	186,800	156,400	305,500	297,700	348,100	308,800
CRV Phase 1 (HSF)		75,000	90,000	75,000			

* Technology Base Program as defined in this table includes all activities that directly or synergistically contribute to meeting space transportation technology goals.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

EARTH SCIENCE BUDGET STRUCTURE CHANGE

NASA has restructured the Earth Science Budget in FY 2001 to display the resources being allocated to Research and Technology requirements in a way that can be more readily understood by NASA's customers. As a result, the Research and Technology requirements have been allocated into three categories: Earth Science Program Science, Applications Commercialization and Education (ACE) and Technology Infusion. This restructured format aligns the Research and Technology requirements with the way that they are managed within the Agency.

Given the complexity of the restructure, NASA has elected to cast the entire Earth Science Budget Narrative in the New Structure. A crosswalk from the Old Structure to the New Structure by Fiscal Year is provided in the Special Issues Section.

The following table summarizes the a Old Structure for FY 1999/FY 2000 and New Structure for FY 2001:

FY 1999 EARTH SCIENCE CROSSWALK

PROPOSED STRUCTURE

		Major Development			Research and Technology				Investment	Operations
		918.6			439.7				0.0	55.5
OLD STRUCTURE	FY1999 Op Plan	EOS	EOSDIS	Earth Probes	Earth Sci Prog Science	Appl Comml & Educ	Tech Infusion	COF	Investments	Ops
Earth Science Total	**1413.8**	**547.6**	**261.7**	**109.3**	**251.8**	**82.9**	**103.5**	**1.5**	**0.0**	**55.5**
EOS	632.4	543.4					89.0			
EOSDIS	261.7		261.7							
Earth Probes	109.3			109.3						
Applied Research and Data Analysis	399.7									
Science	323.6									
Airborne	18.1				18.1					
UAV Science	1.9				1.9					
Commercial remote sensing	38.1					38.1				
Mission Science Teams	48.1				48.1					
R&A (included education and outreach)										
EOS Science	46.4				41.6	4.8				
R&A	161.6				136.0	25.6				
Education	9.4					9.4				
Operations, Data Retrieval, and Stor	76.1									
Mission Ops	55.5									55.5
HPCC	14.5						14.5			
Info Systems	6.1				6.1					
GLOBE	5.0					5.0				
Launch Services	4.2	4.2								
CofF	1.5							1.5		

FY 2000 EARTH SCIENCE CROSSWALK

PROPOSED STRUCTURE

OLD STRUCTURE	FY2000 Op Plan	Major Development 926.4			Research and Technology 469.4				Investment 0.0	Operations 47.6
		EOS	EOSDIS	Earth Probes	Earth Sci Prog Science	Appl Comml & Educ	Tech Infusion	COF	Investments	Ops
Earth Science Total	**1443.4**	**500.9**	**261.9**	**163.6**	**286.3**	**85.7**	**96.4**	**1.0**	**0.0**	**47.6**
EOS	575.4	500.9					74.5			
EOSDIS	261.9		261.9							
Earth Probes	157.4			157.4						
Applied Research and Data Analysis	436.5									
Science	359.4									
Airborne	22.1				22.1					
UAV Science	4.0				4.0					
Commercial remote sensing	30.4					30.4				
Mission Science Teams	55.8				55.8					
R&A (included education and outreach)										
EOS Science	60.3				55.0	5.3				
R&A	174.6				141.8	32.8				
Education	12.2					12.2				
Operations, Data Retrieval, and Stor	77.1									
Mission Ops	47.6									47.6
HPCC	21.9						21.9			
Info Systems	7.6				7.6					
GLOBE	5.0					5.0				
CofF	1.0							1.0		
SRTM	6.2			6.2						

FY 2001 EARTH SCIENCE CROSSWALK

PROPOSED STRUCTURE

		Major Development			Research and Technology				Investments	Operations
		819.5			533.3				10.3	42.7
OLD STRUCTURE	FY 2001 President's Budget	EOS	EOSDIS	Earth Probes	Earth Sci Prog Science	Appl Comml & Educ	Tech Infusion	COF	Investments	Ops
Earth Science Total	**1405.8**	**447.1**	**252.0**	**120.4**	**353.2**	**69.2**	**110.9**	**0.0**	**10.3**	**42.7**
EOS	536.2	447.1					89.1			
EOSDIS	252.0		252.0							
Earth Probes	120.4			120.4						
Applied Research and Data Analysis	481.9									
Science	407.7									
Airborne	22.7				22.7					
UAV Science	5.0				5.0					
Commercial remote sensing	31.9					31.9				
Mission Science Teams	100.0				100.0					
R&A (included education and outreach)										
EOS Science	59.2				52.2	7.0				
R&A	184.8				163.6	21.2				
Education	4.1					4.1				
Operations, Data Retrieval, and Stor	74.2									
Mission Ops	42.7									42.7
HPCC	21.8						21.8			
Info Systems	9.7				9.7					
GLOBE	5.0					5.0				
Investments	10.3								10.3	
SRTM	0			0						

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

AERO-SPACE TECHNOLOGY BUDGET STRUCTURE CHANGE

NASA has combined the Aeronautical Research & Technology and the Advanced Space Transportation Technology budget line items into one Aero-Space Technology budget account. The Congressional budget direction to NASA in House Report 106-145 was to "develop a plan for the integration of research, development, and experimental demonstration activities in the aeronautics transportation technology and space transportation technology areas...[which should] include appropriate strategies for using aeronautics centers in integration efforts." Aero-Space Technology will cover the programmatic work described in the two budget line items in the Science, Aeronautics and Technology Fiscal Year 2000 estimates for the Office of Aero-Space Technology. This restructuring has better aligned the required technology development efforts with core competencies and brought the expertise that is resident in the Aeronautical Research Centers to bear on the technological challenges associated with safe, efficient and affordable space transportation. As a result of this integration, it was possible to develop a technology development program that better utilized our resources, eliminated overlaps, and allowed dual use between aeronautical and space users to be included as part of the planning process.

The following three tables are a crosswalk from the current structure to the proposed structure for FY 1999, FY 2000, and FY 2001:

FY 1999 Budget Crosswalk
(Thousands of Dollars)

	FY 1999 OPLAN 12/23/99	Aero-Space Base Program	Aero-Space Focused Program	Commercial Technology Programs
Aero-Space Technology Summary	1,338,900	488,441	710,107	140,352
Aero-Space Technology Program	768,949			
Aeronautics R&T Base	424,141	424,141		
High-Performance Computing and Communications	20,600		20,600	
Aviation System Capacity	53,888		53,888	
High Speed Research	180,700		180,700	
Advanced Subsonic Technology	89,620		89,620	
Aeronautics Focused Programs	344,808			
Future Space Launch Studies	30,000	30,000		
Pathfinder Technology Demonstrations	36,000		36,000	
Bantam	16,500		16,500	
X-33 Advanced Technology Demonstrator	277,299		277,299	
X-34 Technology Demonstration	35,500		35,500	
Advanced Space Transportation Technology	34,300	34,300		
Advanced Space Transportation	429,599			
Commercial Technology Programs	140,352			140,352

FY 2000 Budget Crosswalk
(Thousands of Dollars)

	FY 2000 OPLAN 12/23/99	Aero-Space Base Program	Aero-Space Focused Program	Commercial Technology Programs
Aero-Space Technology Summary	1,124,854	581,620	403,229	140,005
Research and technology base	581,620	581,620		
High-Performance Computing and Communications	24,200		24,200	
Aviation System Capacity	62,929		62,929	
Aviation Safety	64,394		64,394	
Ultra Efficient Engine Technology	68,306		68,306	
Pathfinder Technology Demonstrations	31,300		31,300	
X-33 Advanced Technology Demonstrator	111,600		111,600	
X-34 Technology Demonstration	40,500		40,500	
Focused programs	403,229			
Commercial Technology Programs	140,005			140,005

FY 2001 Budget Crosswalk
(Thousands of Dollars)

	FY 2001 PRES BUDGET	Aero-Space Base Program	Aero-Space Focused Program	Aero-Space Technology Investments	Commercial Technology Programs
Aero-Space Technology Summary	1,193,000	539,400	507,400	11,200	135,000
Research and technology base	539,400	539,400			
High-Performance Computing and Communications	24,200		24,200		
Aviation System Capacity	59,200		59,200		
Aviation Safety	70,000		70,000		
Small Air Transport System	9,000		9,000		
Quiet Aircraft Technology Program	20,000		20,000		
Ultra Efficient Engine Technology	35,000		35,000		
2nd Generation RLV Focused	235,000		235,000		
Pathfinder Technology Demonstrations	37,100		37,100		
X-34 Technology Demonstration	17,900		17,900		
Focused programs	507,400				
Education Program	2,000			2,000	
Minority University Research and Education Program	9,200			9,200	
Commercial Technology Programs	135,000				135,000

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FISCAL YEAR 2001 BUDGET ESTIMATES

SPACE OPERATIONS BUDGET STRUCTURE CHANGE

Space Operations is a new line item in the SAT budget, beginning in FY 2001. Funding for these activities is consolidated from Space Communications Services, currently part of the Mission Support account, and Mission Communication Services, currently part of the SAT account. This is being done so to link these activities more directly with the agency programs that constitute the principal users of these facilities and services. This will enable the Space Operations Management Office (SOMO) at Johnson Space Center to more effectively manage the Space Operations program. This will ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner.

The following three tables are a crosswalk from the current structure to the proposed structure for FY 1999, FY 2000, and FY 2001:

FY 1999 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 1999 OPLAN 12/23/99	FY 2001 BUDGET STRUCTURE: Operations	Mission and Data Service Upgrades	TDRS Replenishment	Technology
Space Operations Summary	**565,800**	**333,500**	**92,000**	**96,900**	**43,400**
Mission Communications Services	**380,000**	**247,400**	**91,600**		**41,000**
Ground Networks	157,300	104,500	44,800		8,000
DSN Systems	70,400	32,300	30,100		8,000
DSN Operations	53,800	51,200	2,600		
STDN Systems	1,000	300	700		
STDN Operations	7,700	1,400	6,300		
AB&SR Systems	5,100	1,600	3,500		
AB&SR Operations	19,300	17,700	1,600		
Mission Control and Data Systems	213,000	138,300	41,700		33,000
Mission Control Systems	10,000	1,800	8,200		
Mission Control Operations	142,800	124,600	18,200		
Data Processing Systems	42,900	8,500	5,700		28,700
Data Processing Operations	17,300	3,400	9,600		4,300
Space Network Customer Services	9,700	4,600	5,100		
Space Communications Services	**185,800**	**86,100**	**400**	**96,900**	**2,400**
Space Network Services	7,700	7,300	400		
TDRS Replenishment Spacecraft	66,700			66,700	
TDRS Replenishment Launch Services	30,200			30,200	
NASA Integrated Services Network	81,200	78,800			2,400

FY 2000 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 2000 OPLAN REVISED	FY 2001 BUDGET STRUCTURE: Operations	Mission and Data Service Upgrades	TDRS Replenishment	Technology
Space Operations Summary	**496,000**	**326,500**	**97,600**	**31,700**	**40,200**
Mission Communications Services	**406,300**	**269,600**	**581,620**		**39,100**
Ground Networks	159,400	105,000	45,100		9,300
DSN Systems	74,700	31,700	34,300		8,700
DSN Operations	53,300	49,600	3,100		600
STDN Systems	300	300			
STDN Operations	3,600	3,600			
AB&SR Systems.	6,100	500	5,600		
AB&SR Operations	21,400	19,300	2,100		
Mission Control and Data Systems	242,000	161,300	50,900		29,800
Mission Control Systems	9,700	100	9,600		
Mission Control Operations	182,700	146,400	36,300		
Data Processing Systems	41,000	8,400	2,800		29,800
Data Processing Operations	8,600	6,400	2,200		
Space Network Customer Services	4,900	3,300	1,600		
Space Communications Services	**89,700**	**56,900**		**31,700**	**1,100**
Space Network Services	4,400	4,400			
TDRS Replenishment Spacecraft	17,700			17,700	
TDRS Replenishment Launch Services	14,000			14,000	
NASA Integrated Services Network	53,600	52,500			1,100

FY 2001 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 2001 PRES BUDGET	FY 2001 BUDGET STRUCTURE: Operations	Mission and Data Service Upgrades	TDRS Replenishment	Technology
Space Operations Summary	**529,400**	**329,800**	**106,200**	**55,000**	**38,400**
Mission Communications Services	**422,000**	**278,300**	**106,200**		**37,500**
Ground Networks	158,600	107,900	44,500		6,200
DSN Systems	71,100	31,600	33,800		5,700
DSN Operations	56,400	52,700	3,200		500
STDN Systems	1,300	200	1,100		
STDN Operations	3,400	3,200	200		
AB&SR Systems	5,300	800	4,500		
AB&SR Operations	21,100	19,400	1,700		
Mission Control and Data Systems	254,600	168,200	55,100		31,300
Mission Control Systems	8,200	100	8,100		
Mission Control Operations	196,000	154,700	41,300		
Data Processing Systems	40,100	9,400	2,600		28,100
Data Processing Operations	10,300	4,000	3,100		3,200
Space Network Customer Services	8,800	2,200	6,600		
Space Communications Services	**107,400**	**51,500**		**55,000**	**900**
Space Network Services	4,800	4,800			
TDRS Replenishment Spacecraft	14,500			14,500	
TDRS Replenishment Launch Services	40,500			40,500	
NASA Integrated Services Network	47,600	46,700			900

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

SPACE SHUTTLE BUDGET STRUCTURE CHANGE

This FY 2001 Request is submitted in a restructured budget format for the Space Shuttle Program. The old nomenclature, "Safety and Performance Upgrades" (S&PU), will no longer be used as a budgetary naming convention. The new structure provides much more clarity with the Upgrades activity and recent augmentations included in this request. The S&PU as a budget category included many other items in addition to Upgrades, which led to confusion as to what were and were not considered upgrades. Under the new structure, upgrades are clearly delineated under each of the four line items of Flight Hardware, Ground Operations, Program Integration and Flight Operations.

The following three tables are a crosswalk from the current structure to the proposed structure for FY 1999, FY 2000, and FY 2001:

FY 1999 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 1999 OPLAN 12/23/99	FY 2001 BUDGET STRUCTURE: Flight Hardware	Ground Operations	Flight Operations	Program Integration
Space Shuttle Total	**2,998,300**	**1,868,400**	**549,100**	**286,800**	**294,000**
Shuttle Operations	**2,426,700**	**1,480,800**	**450,100**	**253,000**	**242,800**
Orbiter and Integration	608,000	463,300			144,700
Propulsion	1,071,200	1,017,500			53,700
External Tank	363,200	363,200			
Space Shuttle Main Engine	200,000	146,300			53,700
Reusable Solid Rocket Motor	339,000	339,000			
Solid Rocket Booster	169,000	169,000			
Mission and Launch Operations	747,500		450,100	253,000	44,400
Safety and Performance Upgrades	**571,600**	**387,600**	**99,000**	**33,800**	**51,200**
Orbiter Improvements	234,800	211,900			22,900
Propulsion Upgrades	175,700	175,700			
Flight Operations and Launch Site Equipment	147,600		99,000	33,800	14,800
Construction of Facilities	13,500				13,500

FY 2000 Budget Crosswalk
(Thousands of Dollars)

		FY 2001 BUDGET STRUCTURE			
FY 2000 BUDGET STRUCTURE	FY 2000 OPLAN REVISED	Flight Hardware	Ground Operations	Flight Operations	Program Integration
Space Shuttle Total	**2,979,500**	**1,884,600**	**510,300**	**244,600**	**340,000**
Shuttle Operations	**2,490,700**	**1,496,100**	**459,000**	**227,500**	**308,100**
Orbiter and Integration	698,800	500,100			198,700
Propulsion	1,053,100	996,000			57,100
External Tank	355,200	355,200			
Space Shuttle Main Engine	187,500	130,400			57,100
Reusable Solid Rocket Motor	356,700	356,700			
Solid Rocket Booster	153,700	153,700			
Mission and Launch Operations	738,800		459,000	227,500	52,300
Safety and Performance Upgrades	**488,800**	**388,500**	**51,300**	**17,100**	**31,900**
Orbiter Improvements	183,700	175,300			8,400
Propulsion Upgrades	213,200	213,200			
Flight Operations and Launch Site Equipment	80,900		51,300	17,100	12,500
Construction of Facilities	11,000				11,000

FY 2001 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 2001 PRES BUDGET	FY 2001 BUDGET STRUCTURE: Flight Hardware	Ground Operations	Flight Operations	Program Integration
Space Shuttle Total	**3,165,700**	**2,005,900**	**551,800**	**273,600**	**334,400**
Shuttle Operations	**2,672,800**	**1,630,300**	**481,100**	**263,900**	**297,500**
Orbiter and Integration	724,500	506,200			218,300
Propulsion	1,167,400	1,124,100			43,300
External Tank	349,700	349,700			
Space Shuttle Main Engine	261,900	218,600			43,300
Reusable Solid Rocket Motor	418,300	418,300			
Solid Rocket Booster	137,500	137,500			
Mission and Launch Operations	780,900		481,100	263,900	35,900
Safety and Performance Upgrades	**492,900**	**375,600**	**70,700**	**9,700**	**36,900**
Orbiter Improvements	327,200	315,400			11,800
Propulsion Upgrades	60,200	60,200			
Flight Operations and Launch Site Equipment	90,000		70,700	9,700	9,600
Construction of Facilities	15,500				15,500

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2001 BUDGET ESTIMATES

HUMAN SPACE FLIGHT BUDGET STRUCTURE CHANGE

The Paylaod Utilization and Operations line item has been deleted beginning in FY 2001. In its place, two new line items, have been created - Paylaod and ELV Support and Invesments and Support. The Payload Carriers and Support and the ELV Mission Support budgets, currently part of the Paylaod Utilization and Operations line are moved into the new Paylaod and ELV Support line item as a stand-along activity.

Investments and Support is the second new line item in the HSF budget, beginning in FY 2001. Funding for these activities is consolidated from Engineering and Technical Base, currently part of the Paylaod Utilization and Operations account, and various activities scattered in other programs in the HSF and Mission Support approproations. This is being done so as to link these activities more directly with the agency programs that constitute the principal users of these facilities and services. This will enable the Office of Space Flight to more effectively manage these projects and ensure that the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner.

The following tables are a crosswalk from the current structure to the proposed structure for FY 1999, FY 2000, and FY 2001:

FY 1999 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 1999 OPLAN 12/23/99	FY 2001 BUDGET STRUCTURE: Payload and ELV Support	FY 2001 BUDGET STRUCTURE: Investments and Support
Total Payload Utilization and Operations	**182.0**	**70.7**	**111.3**
Payload Carriers and Support	39.2	39.2	
ELV Mission Support	31.5	31.5	
Advanced Projects	15.0		15.0
Engineering and Technical Base	96.3		96.3

FY 2000 BUDGET STRUCTURE	FY 1999 OPLAN 12/23/99	FY 2001 BUDGET STRUCTURE: Rocket Propulsion Test	FY 2001 BUDGET STRUCTURE: OSF Contrib. to Academic Programs	FY 2001 BUDGET STRUCTURE: Advanced Projects	FY 2001 BUDGET STRUCTURE: Engineering and Technical Base
Total Investments and Support	**132.5**	**23.7**	**3.1**	**15.0**	**90.7**
Human Space Flight	**123.7**	**14.9**	**3.1**	**15.0**	**90.7**
International Space Station					
Space Shuttle	12.4	11.6	0.8		
Payload Utilization and Operations	111.3	3.3	2.3	15.0	90.7
Advanced Projects	15.0			15.0	
Engineering and Technical Base	96.3	3.3	2.3		90.7
Mission Support	**8.8**	**8.8**			
Research and Program Management	8.8	8.8			
Research Operations Support	8.8	8.8			

FY 2000 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 2000 OPLAN REVISED	FY 2001 BUDGET STRUCTURE: Payload and ELV Support	FY 2001 BUDGET STRUCTURE: Investments and Support
Total Payload Utilization and Operations	**165.1**	**79.9**	**85.2**
Payload Carriers and Support	49.3	49.3	
ELV Mission Support	30.6	30.6	
Engineering and Technical Base	85.2		85.2

FY 2000 BUDGET STRUCTURE	FY 2000 OPLAN REVISED	FY 2001 BUDGET STRUCTURE: Rocket Propulsion Test	FY 2001 BUDGET STRUCTURE: OSF Contrib. to Academic Programs	FY 2001 BUDGET STRUCTURE: Advanced Projects	FY 2001 BUDGET STRUCTURE: Engineering and Technical Base
Total Investments and Support	**106.9**	**24.5**	**3.1**	--	**79.3**
Human Space Flight	**97.2**	**14.8**	**3.1**		**79.3**
International Space Station	0.5	0.5			
Space Shuttle	11.5	10.7	0.8		
Payload Utilization and Operations	85.2	3.6	2.3		79.3
Engineering and Technical Base	85.2	3.6	2.3		79.3
Mission Support	**9.7**	**9.7**			
Research and Program Management	9.7	9.7			
Research Operations Support	9.7	9.7			

FY 2001 Budget Crosswalk
(Thousands of Dollars)

FY 2000 BUDGET STRUCTURE	FY 2001 PRES BUDGET	FY 2001 BUDGET STRUCTURE: Payload and ELV Support	FY 2001 BUDGET STRUCTURE: Investments and Support
Total Payload Utilization and Operations	**193.3**	**90.2**	**103.1**
Payload Carriers and Support	57.0	57.0	
ELV Mission Support	33.2	33.2	
Technology and Commercialization	20.0		20.0
Engineering and Technical Base	83.1		83.1

FY 2000 BUDGET STRUCTURE	FY 2001 PRES BUDGET	FY 2001 BUDGET STRUCTURE: Rocket Propulsion Test	FY 2001 BUDGET STRUCTURE: OSF Contrib. to Academic Programs	FY 2001 BUDGET STRUCTURE: Technology and Commercial	FY 2001 BUDGET STRUCTURE: Engineering and Technical Base
Total Investments and Support	**129.5**	**28.0**	**8.0**	**20.0**	**73.5**
Human Space Flight	**116.8**	**15.3**	**8.0**	**20.0**	**73.5**
International Space Station	0.5	0.5			
Space Shuttle	13.2	10.9	2.3		
Payload Utilization and Operations	103.1	3.9	5.7	20.0	73.5
Technology and Commercialization	20.0			20.0	
Engineering and Technical Base	83.1	3.9	5.7		73.5
Mission Support	**12.7**	**12.7**			
Research and Program Management	12.7	12.7			
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NASA FY 2001 Performance Plan

Background and Introduction

The Government Performance and Results Act

The Government Performance and Results Act (GPRA) was passed by Congress and signed by the President in 1993. GPRA was enacted to improve the efficiency of all Federal agencies, with the following specific goals:

Improve Federal program management, effectiveness, and public accountability

- Improve congressional decisionmaking on where to commit the Nation's financial and human resources
- Improve citizen confidence in Government performance

The Act directs Executive Branch agencies to develop a customer-focused strategic plan that aligns activities with concrete missions and goals. The first strategic plans were to be submitted in September 1998 as part of the Fiscal Year 1999 (FY 1999) budget process. The budget submissions were to support the goals expressed in the agency strategic plans. The Act also directs agencies to manage and measure results to justify Congressional appropriations and authorizations. Six months after the completion of the fiscal year, agencies will report on the degree of success in achieving the goals and evaluation measures defined in the strategic and performance plans. The first such report will be furnished to the Congress in March 2000, covering the performance in FY 1999.

NASA's Strategic Management System

Processes within NASA's Strategic Management System provide the information and results for GPRA's planning and reporting requirements. The System is defined in the NASA Strategic Management Handbook (NASA Procedures and Guidelines 1000.2). Figure 1 illustrates the hierarchy of documentation for the Strategic Management System.

The NASA Strategic Plan (NASA Policy Directive 1000.1) defines the vision, mission, and fundamental questions of science and research that provide the foundation of the Agency's goals. The Plan describes four Strategic Enterprises that manage the programs and activities to implement our mission, answer the fundamental questions, and provide service to identified customers. These Strategic Enterprises are *the Space Science Enterprise, the Earth Science Enterprise, the Human Exploration and Development of Space Enterprise, and the Aero-Space Technology Enterprise.* The support systems for the Strategic Enterprises, defined as Crosscutting Processes, are also defined in the Strategic Plan. These Crosscutting Processes are *Manage Strategically, Provide Aerospace Products and Capabilities, Generate Knowledge, and Communicate Knowledge.*

Interested readers may access these Strategic Management System documents through the Internet.

It should also be noted that the Final FY 2001 Performance Plan reflects the Strategic Plan in force at the time the President's Budget was released. NASA is currently working on the next Strategic Plan, due to be released in September 2000.

In the NASA Strategic Plan, the vision and mission statements of the Agency are articulated. We reprint them here for the convenience of the reader.

NASA Vision Statement

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

NASA Mission Statement

- ***To advance and communicate scientific knowledge and understanding of the Earth, the solar system, and the universe and use the environment of space for research;***
- ***To advance human exploration, use, and development of space;***
- ***To research, develop, verify, and transfer advanced aeronautics, space, and related technologies.***

Outcomes of NASA's Activities

Government investment decisions on funding for space and aeronautics research and technology cannot be made knowing in advance the full benefits ("outcomes") that will accrue from making the investments. Nor, can the timetable be known as to when these benefits will be realized. However, we can identify how the outcomes of NASA's activities contribute significantly to the achievement of America's goals in four key areas:

Economic growth and security – NASA conducts aeronautics and space research and develops technology in partnership with industry, academia, and other federal agencies to keep America capable and competitive.

Educational Excellence – NASA involves the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds.

Peaceful Exploration and Discovery – NASA explores the Universe to enrich human life by stimulating intellectual curiosity, opening new worlds of opportunity, and uniting nations of the world in this quest.

Preserving the Environment – NASA studies the Earth as a planet and as a system to understand global climate change, enabling the world to address environmental issues.

Performance targets supporting the first three outcomes can be found in all of the Enterprises and Crosscutting Processes. Performance targets supporting the preservation of the environment can be found in the Earth Science Enterprise.

NASA's Fiscal Year 2001 Budget

The NASA FY01 budget request (Figure 3) reaffirms the President's commitment to support NASA's space and aeronautics program. This budget will support the Agency's priorities as directed by the National Space Policy and the President's Goals for a National Partnership in Aeronautics Research and Technology. NASA's priorities include a commitment to safety for human aeronautics and space flight, the assembly of the International Space Station, and the development of the Next Generation Launch Vehicle. The budget also provides support for an aggressive space science program, a program of long-term observation, research and analysis of Earth from space and revolutionary advancements that will sustain global U.S. leadership in civil aeronautics and space.

The successful execution of NASA's strategic goals and objectives is contingent on receipt of the requested appropriations, as well as the provision of funds, materials, or services which have been committed to the cooperative agreements or partnerships that are referenced in this document. The parties to these agreements include: foreign governments, other Federal Agencies or Departments, and commercial entities.

Fiscal Year 2001 Estimates
(In millions of Real Year Dollars)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
NASA Total Budget $M	13,653	13,601	14,035	14,465	14,769	15,305	15,570
Space Science	2,119	2,193	2,399	2,606	2,961	3,299	3,578
Earth Science	1,414	1,443	1,406	1,333	1,293	1,303	1,306
Human Exploration & Development of Space*	6,309	6,238	6,332	6,189	5,629	5,442	5,313
Aero Space Transportation Technology	1,339	1,125	1,193	1,549	1,949	2,245	2,303
Mission Support/IG/Other	2,472	2,601	2,706	2,789	2,936	3,017	3,071
Civil Servant FTEs	18,469	18,623	18,954	18,970	18,971	18,777	18,562

The Mission Support line includes the indirect cost of operating the NASA institution, including personnel providing direct and indirect support.

Under the FY2001 submission structure, the cost of Full Time Equivalents and related travel directly supporting the Projects and Programs of the various Enterprises are displayed in the Mission Support account. As NASA moves into the era of full cost

management, the budget for the Mission Support and Other elements will be directly allocated to the programs and projects.

For informational purposes, the Enterprise sections of this plan will display the Civil Service staffing levels assigned to the Enterprise. There are also tables in each of the sections that provide the reader with a crosswalk between the performance targets, the strategic objectives and the appropriate budget line item.

Additional detail on the means and strategies for accomplishing these performance targets is included in the budget narrative sections of this document. The NASA FY01 Budget is also available through the NASA homepage at the following internet address: http://ifmp.nasa.gov/codeb/budget2001/

NASA Performance Plan

This document, as required by GPRA, describes performance measures and service levels for program activities requested in the FY01 budget. Performance goals and objectives are defined for NASA's Strategic Enterprises and for Crosscutting Processes in the *NASA Strategic Plan, with 1999 Interim Adjustments (NPD 1000.1).*

NASA has instituted several major changes with the FY01 Performance Plan. NASA has revised its approach to the development of performance targets. The targets contained in the FY01 Performance Plan have been developed to enable a better understanding of how the specific measures of output (indicators) contribute to the eventual outcomes that are the result of a number of years of research, development, and data analysis. The performance targets in the FY01 Performance Plan have been developed specifically to enable us to display indicators from multiple years which will contribute to the achievement of the summary targets. This change in format will ultimately allow a more concise representation of the agency's performance that will more readily span multiple years and enable decisionmaking of the type intended by the authors of GPRA. NASA believes that this process improvement will better serve the needs of the public, our governmental customers and agency management.

This plan thus represents a transition which must bridge the distance between the previous approach and the future more concise representation. Performance targets from previous performance plans more closely approximate the indicators in the FY01 Performance Plan. The Indicators supporting each of the performance targets are identified in an appendix to this plan.

Following the narrative sections, each Enterprise or Crosscutting Process will include the following displays:

- A table which relates the Strategic Goals, Strategic Objectives, and FY01 Performance Targets. The types of indicators being used to evaluate performance against those targets are characterized in the final column.
- A table which recaps the relationship of budget account, target, and performance indicators.

To facilitate configuration management, control numbers have been assigned to all performance targets. The numbering sequences may not be contiguous, as targets may have been dropped out as the formulation process progressed.

The Performance Evaluation Process

NASA uses a process of extensive internal and external reviews to evaluate our progress against established plans.

Internally, there are standard monthly and quarterly project and program level reviews at the NASA field installations, at contractor installations, and at NASA Headquarters. There are regular reviews for functional management activities, such as procurement, finance, facilities, personnel, information resources management, etc. There are reviews of science, engineering, and technology plans and performance. The NASA Inspector General conducts independent reviews and provides recommendations for corrective actions.

NASA has established management councils, as described in the NASA Strategic Management Handbook, that conduct internal oversight reviews. Throughout the year, Program Management Councils (PMCs) at Headquarters and the Centers assess program schedules, cost, and technical performance against established programmatic commitments. The Senior Management Council (SMC) brings together both Headquarters and Field Installation Directors to conduct assessment review twice a year of the progress being made in meeting the Enterprise and Crosscutting Process performance targets.

NASA's extant management review processes provide appropriate forums for internal reporting and reviewing of project and program performance data. The recent streamlining of agency processes provides confidence that new data collection and oversight processes need not be created for compliance with GPRA. Our mission oriented organizational structure and established management processes are well suited to assessment of this type of performance evaluation.

There are also significant external review processes in place. The external reviews typically begin with the peer review processes in which NASA uses panels of outside scientific experts to ensure that science research proposals are selected strictly on the merits of the planned research. This process takes into account past performance for selection and/or continued funding.

External reviews of agency performance are conducted by a number of organizations. An independent accounting firm annually audits NASA's financial statements, including program and functional performance parameters, which leads to the publication of the *Accountability Report*. NASA requests assistance from other federal agencies to provide expert advice and council. In some cases, the organizations are advisory bodies of experts from the public and private sectors that work with NASA to establish priorities in particular scientific disciplines. In other cases, reviews are conducted by organizations such as the NASA Advisory Council, the Aerospace Safety Advisory Panel, the National Academy of Sciences, and the General Accounting Office, which share responsibility for oversight of the Agency. The Occupational Safety and Health Administration and the Environmental Protection Agency will also provide reviews of performance unique to their agencies during the fiscal year.

The use of these external reviews allows NASA to receive a report card on whether we are making the anticipated progress towards accomplishing the priorities established by the Administration, the Congress, and our advisory bodies. When necessary, these external assessments result in the revision of either implementation plans or strategic plans.

The GPRA Performance Evaluation and Report Process

For the purposes of the GPRA performance reporting process, NASA intends to use NASA's advisory committees as the critical input. These committees already opine on NASA's Strategic Plan, individual Enterprise Strategic Plans, and budgetary priorities. NASA furnishes program performance status information, and in turn, the committees render advice and council. It is this process that NASA will employ to generate an independent "scorecard" report on our annual performance.

NASA has historically been one of the most open federal agencies in terms of performance measurements. Public attention is drawn quickly to program successes, and particularly to program failures. Press conferences on the scientific results and program technical status are commonplace. The technical measurement of program progress is a management imperative due to the heavy emphasis on development programs, and within the programs, the specific projects. Flight programs such as the International Space Station compile thousands of technical performance metrics, schedule milestones, and cost performance data.

However, the GPRA requires a heavier focus on outcome metrics rather than NASA's ubiquitous input and output metrics. Like other federal agencies engaged in science and technology, NASA has difficulty in quantifying outcomes and, especially, relating current outcomes to current fiscal expenditures. This is particularly the case since NASA development programs are multi-year in character. In some cases, the past expenditures began more than a decade ago, such as the Hubble Space Telescope that entered into development in the mid-1970's. More recently, NASA has focussed on programs and projects with much shorter development periods, on the order of 3-5 years. Yet, the science outcomes are dependent on scientists analyzing the information gathered in the years after launch.

The stated objectives of programs within NASA's Enterprises are long-term in character. This is exemplified by considering a Space Science performance objective, "Solve the mysteries of the universe." Annual performance evaluations assess whether appropriate progress is being made, perhaps actually solving individual "mysteries" to the satisfaction of the scientific community, or providing additional insights to the eventual solution of other mysteries. The assessment process requires a multifaceted judgement which takes into account the nature of the challenge of "solving the mystery," the level of resources available to be applied, and the actual scientific achievements of the past year.

It is particularly important in our view to avoid evaluating actual output performance in R&D organizations solely by counting the number of planned events for the year with the number that actually occurred. The "beancount" approach is more appropriate to a known manufacturing environment. In the high-performance, high-risk R&D environment that characterizes NASA's programs, it is

inadvisable to incentivize on-time performance and thereby de-emphasize safety, quality, high performance and appropriate risk-taking.

NASA has worked hard to maintain the highest emphasis on maintaining safety; this value applies not only to safety of personnel but also to preservation of high value facilities, equipment, experimental hardware, and related capabilities. Quality goes hand-in-hand with safety, but extends well beyond it. For example, taking credit for completing a critical design review (CDR) for a spacecraft is only appropriate when the CDR process has been thorough, complete, and meets performance standards. Great care must be taken that quality does not suffer when contract fee incentives call for a milestone payment upon completion of the CDR. Other examples abound, and give rise to our constant vigilance to avoid rushing to launch in order to achieve a given date.

It is possible, of course, to emphasize safety and quality and achieve little of lasting significance or have the achievement take an inordinate amount of time. Building spacecraft that do not test new designs, but rely only on proven designs, is appropriate for operational, mission agencies or commercial entities. It is not appropriate for an R&D environment. Conducting basic and applied research involves experimentation. Exploration of new methods and new technologies in these high-performance ventures, it is acceptable to take risks, to push the envelope, to fail. The tolerance of failure puts NASA and other R&D agencies into a different category than other federal agencies involved in the delivery of services to the public. Note, however, that this does not translate into an acceptance of failures that result from taking an inappropriate level of risk. The level of appropriate risk is tailored to the environment. The distinction is critical, particularly in high-value, high-cost environments, such as human space flight, the maintenance of the Hubble Space Telescope, and the launch of the Cassini spacecraft. The risk of failure in those venues is limited by all practicable means.

Thus, output measures are best used in suitable context. For these reasons, NASA management encourages Space Shuttle program managers to shunt aside metrics dealing with launches planned vs. launches achieved during a given fiscal year. If by waiting, one less launch is achieved than planned, but the result is better safety or quality or enables improved performance or reduces risk, then the latter result is what NASA wants to incentivize.

We have met with little success in past efforts to marry conventional output measures to these other parameters to derive a quantitative performance metric. Instead, we have determined that asking independent experts to review both quantitative and qualitative measures and to come up with an integrated score is a better approach.

For the purpose of assessing NASA's overall performance, we will continue to ask our Advisory Committees to evaluate accomplishments at the level of the Enterprise and Crosscutting Process objectives, integrating not only quantitative output measures but also balancing these in the context of safety, quality, high performance, and appropriate risk. The Advisory Committees will be asked to assign a rating of "red, yellow, or green" to measure the progress made against each of the objectives, and provide a narrative explanation. These objectives are identified in the Strategic Plan and repeated in the display of Strategic Goals and Strategic Objectives.

Space Science Enterprise

Mission

The primary Goal of the Space Science Enterprise is to chart the evolution of the universe from origins to destiny, and improve understanding of galaxies, stars, planets, and life (Figure 2). Within this Goal, Enterprise Objectives are to solve mysteries of the universe, explore the solar system, discover planets around other stars, and search for life beyond Earth. Other Enterprise Goals include developing innovative technologies to support Space Science programs and making them available for other applications that benefit the Nation. Enterprise missions and research also yield scientific information of value for future exploration programs. Knowledge and discoveries will be shared with the public to enhance science, mathematics, and technology education and increase the scientific and technological literacy of all Americans.

Implementation Strategy

The Space Science Enterprise is continuing to develop new programs through the "faster, better, cheaper" approach. Program managers are encouraged to shorten the development time of technologies and missions, explore new conceptual approaches, streamline management, and incorporate innovative methods and technologies to enhance efficiency and effectiveness while maintaining safety. Continuing investment in long-term, high-payoff technologies, such as advanced miniaturization, intelligent systems, autonomous operations, and simulation-based design, are key to implementing the Space Science mission. Collaborative efforts with other Federal agencies, such as the National Science Foundation, Department of Defense and Department of Energy, as well as with international partners, play a key role in the implementation strategy of the Enterprise.

Enterprise Resource Requirements

The President has requested the following budget for FY99 to FY05 to support the accomplishment of Space Science goals:

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
NOA $M	2,119	2,193	2,399	2,606	2,961	3,299	3,578
CS FTEs	1,846	1,751	1,740	1,728	1,745	1,750	1,762

Performance Measures

The following measures summarize individual targets and indicators for Enterprise programs:

Goal: Chart the evolution of the universe from origins to destiny, and understand its galaxies, stars, and life.

Objective: Solve Mysteries of the Universe

- Successfully develop and launch no less than three of four planned missions within 10% of budget and schedule; an example is the Microwave Anisotropy Probe (MAP) (Target: 1S1).
- Obtain expected scientific data from 80% of operating missions; examples are the Chandra X-ray Observatory (CXO) and the Far Ultraviolet Spectroscopy Explorer (FUSE) (Target: 1S2).
- Perform innovative scientific research and technology development by meeting technology development objectives for major projects (for example, the Next Generation Space Telescope, NGST), by achieving a mission success rate of 80% for astronomy rocket and balloon flights, and by making satisfactory research progress in related Research and Analysis (R&A) and Data Analysis (DA) programs (Target: 1S3).

Objective: Explore the Solar System

(This objective includes missions to increase our understanding of the Sun and its effects on the Earth, as well as missions to explore the solar system.)

- Successfully develop and launch no less than one of two missions within 10% of budget and schedule; an example is the Mars 01 Orbiter (Target: 1S4).
- Obtain expected scientific data from 80% of operating missions; examples are the Cassini and Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) missions (Target: 1S5).
- Perform innovative scientific research and technology development by meeting technology development objectives for major projects (for example, the Solar-Terrestrial Relations Observatory, STEREO), by achieving a mission success rate of 80% for space physics rocket and balloon flights, and by making satisfactory research progress in related R&A and DA programs (Target: 1S6).

Objective: Discover Planets Around Other Stars

- Perform innovative scientific research and technology development by meeting interferometry technology development objectives (for example, for the Space Interferometry Mission, SIM) and by making satisfactory research progress in related R&A programs (Target: 1S7).

Objective: Search for Life Beyond Earth

- Perform innovative scientific research and technology development by meeting technology development objectives for the Europa Orbiter and by making satisfactory research progress in the related R&A program, including the Astrobiology program (Target: 1S8).

Goal: Contribute measurably to achieving the science, math, and technology education goals of our nation.

Objective: Make education and enhanced public understanding of science an integral part of our missions and research

- Continue and expand the integration of education and enhanced public understanding of science with Enterprise research and flight mission programs, including planning or implementing funded education and outreach activities in at least 34 states (Target: 1S9).

Goal: Support human exploration through robotic missions.

Objective: Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies

- Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies by successfully launching the Mars 01 Orbiter, by obtaining data from operational spacecraft (for example, the Mars Global Surveyor), and by making satisfactory progress in related R&A and DA programs (Target: 1S10).

Objective: Develop the knowledge to improve the reliability of space weather forecasting

- Develop the knowledge to improve the reliability of space weather forecasting by obtaining scientific data from three of five missions (for example, the Transition Region and Coronal Explorer, TRACE) and by making satisfactory progress in related areas in R&A and DA programs (Target: 1S11).

Goal: Develop new technologies needed to carry out innovative and less costly mission and research concepts

Objective: Develop new technologies needed to carry out innovative and less costly mission and research concepts

- Plan, develop, and validate new technologies needed to enable future research and flight missions by achieving performance objectives in the space science core technology programs (information systems, high performance computing, and Explorer program technology) and by making progress as planned in the Flight Validation program (Target: 1S12).

NEW INITIATIVE

New Initiative: Living With a Star

- Further understanding of basic natural processes and the effects of solar variability on humans and technology by achieving performance objectives for development of a strategic plan, completion of a mission definition study, and the initiation of targeted research and data analysis.

Internal Assessment

The Space Science program consists of numerous diverse components, and each component's performance must be assessed in an appropriate way. For some program elements, such as mission development, achievement of major milestones is easily identified through routine project management reviews. For missions in an operational phase, success can be gauged in terms of operating efficiency or major data sets returned. For technology programs, progress can be predicted and measured in terms of technical capabilities achieved or successful laboratory or flight tests. In each of these cases, performance assessment data can be retrieved from normal project management reporting during the course of the fiscal year.

External Assessment

For the basic research programs, evaluation must consider important contextual factors such as: the relative value of the research objectives; progress toward those objectives; productivity by prevailing research community standards; and impact on related research funded or performed by other agencies. Measures such as number of grants or scientists supported, publication counts, or research citations are not able to capture these important aspects of the evaluation requirement. The best way to assess research programs has been demonstrated to be an external peer review or visiting committee approach. The Enterprise will employ this mechanism to qualitatively assess the progress of its programs in basic research and data analysis against Enterprise strategic plan science goals and objectives. The reviews will determine whether these investigation programs are fully effective, are not as strong as desired but have returned results of significant value, or are not scientifically or technologically competitive. The review process will also identify those programs that have produced important unexpected results or have contributed to an unanticipated degree to other research.

Space Science Enterprise FY 01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**#**	**FY01 Target**	**FY01 Indicator**
Chart the evolution of the universe, from origins to destiny, and understand its galaxies, stars, and life	Solve Mysteries of the Universe	1S1	Successfully develop and launch no less than three of four planned missions within 10% of budget and schedule.	Performance indicators have been identified for four missions scheduled to launch in FY01; an example is the Microwave Anisotropy Probe (MAP). Indicators have also been established for other missions in development.
		1S2	Obtain expected scientific data from 80% of operating missions.	Performance indicators have been identified for six operating missions [examples are the Chandra X-ray Observatory (CXO) and the Far Ultraviolet Spectroscopy Explorer (FUSE)]. An indicator has also been established for another mission scheduled to launch in FY01; this indicator is to be utilized upon successful launch.
		1S3	Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in astronomy rocket and balloon flights, and by making satisfactory research progress in related Research and Analysis (R&A) and Data Analysis (DA) programs.	Performance indicators have been drawn from technology development objectives for three missions; an example is the Next Generation Space Telescope (NGST). Indicators have also been established for achievement of mission success for astronomy rocket and balloon flights and research progress in the R&A and DA programs.
	Explore the Solar System	1S4	Successfully develop and launch no less than one of two missions within 10% of budget and schedule.	Performance indicators have been identified for two missions scheduled to launch in FY01; an example is the Mars 01 Orbiter. Indicators have also been established for other projects in development.
		1S5	Obtain expected scientific data from 80% of operating missions.	Performance indicators have been identified for nine operating missions [examples are the Cassini and Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) missions]. Indicators have also been established for other missions scheduled to launch in FY01; these indicators are to be utilized upon successful launch.
		1S6	Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in space physics rocket and balloon flights, and by making satisfactory research progress in related R&A and DA programs.	Performance indicators have been drawn from technology development objectives for three missions, as well as for future mission sets and for specific multi-mission technology development efforts. An example of the individual missions is the Solar-Terrestrial Relations Observatory (STEREO). Indicators have also been established for achievement of mission success for space physics rocket and balloon flights and research progress in the R&A and DA programs.

Space Science Enterprise FY 01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**#**	**FY01 Target**	**FY01 Indicator**
	Discover Planets Around Other Stars	1S7	Perform innovative scientific research and technology development by meeting interferometry technology development objectives and by making satisfactory research progress in related R&A programs.	Performance indicators have been drawn from technology development objectives for three missions; an example is the Space Interferometry Mission (SIM). Indicators have also been established for the Keck Interferometer project and for achievement of research progress in the R&A program.
	Search for Life Beyond Earth	1S8	Perform innovative scientific research and technology development by meeting technology development objectives and by making satisfactory research progress in the related R&A program, including the Astrobiology program.	Performance indicators have been drawn from the technology development objectives for the Europa Orbiter. Indicators have also been established for achievement of research progress in the R&A program, including especially the Astrobiology program.
Contribute measurably to achieving the science, math, and technology education goals of our nation.	Make education and enhanced public understanding of science an integral part of our missions and research	1S9	Continue and expand the integration of education and enhanced public understanding of science with Enterprise research and flight mission programs.	Performance indicators have been identified for education and public outreach efforts. These indicators include the planning or implementation of funded education or outreach activities in at least 34 states.
Support human exploration through robotic missions	Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies	1S10	Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies by successfully launching a Mars mission, by obtaining data from operational spacecraft, and by making satisfactory progress in related R&A and DA programs.	Performance indicators have been identified for the Mars '01 Orbiter, scheduled to launch in FY01, and for a Discovery mission scheduled to be in development. Other indicators have also been identified for an operating mission, as well as for achievement of research progress in related R&A and DA programs.
	Develop the knowledge to improve the reliability of space weather forecasting	1S11	Develop the knowledge to improve the reliability of space weather forecasting by obtaining scientific data from three of five missions and by making satisfactory progress in related areas in R&A and DA programs.	Performance indicators have been identified for four operating missions; an example is the Transition Region and Coronal Explorer (TRACE). Indicators have also been established for another mission scheduled to launch in FY01 (to be utilized upon successful launch), as well as for achievement of research progress in the R&A and DA programs.
Develop new technologies needed to carry out innovative and less costly mission and research concepts	Develop new technologies needed to carry out innovative and less costly mission and research concepts	1S12	Plan, develop, and validate new technologies needed to enable future research and flight missions by achieving performance objectives in the space science core technology programs and by making progress as planned in the Flight Validation program.	Performance indicators have been identified for the space science core technology programs (information systems, high performance computing, and Explorer program technology), as well as for the Flight Validation program.

Space Science Enterprise FY 01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**#**	**FY01 Target**	**FY01 Indicator**
New Initiative	Living With a Star		Further understanding of basic natural processes and the effects of solar variability on humans and technology.	Performance indicators have been established for the development of the Living With a Star Strategic Plan, completion of a mission definition study, and the initiation of targeted research and data analysis.

SSE FY01	Budget Category	SIRTF	HST Development	GP-B	SOFIA	Payloads	Explorers	Discovery	Mars Surveyor	Operating Missions	SR&T
Performance Target											
Solve Mysteries of the Universe: Successfully develop and launch no less than three of four planned missions within 10% of budget and schedule. (1S1)		X	X	X	X	X	X				
Solve Mysteries of the Universe: Obtain expected scientific data from 80% of operating missions. (1S2)										X	
Solve Mysteries of the Universe: Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in astronomy rocket and balloon flights, and by making satisfactory research progress in related Research and Analysis (R&A) and Data Analysis (DA) programs. (1S3)											X
Explore the Solar System: Successfully develop and launch no less than one of two missions within 10% of budget and schedule. (1S4)						X	X	X	X		
Explore the Solar System: Obtain expected scientific data from 80% of operating missions. (1S5)										X	
Explore the Solar System: Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in space physics rocket and balloon flights, and by making satisfactory research progress in related R&A and DA programs. (1S6)											X
Discover Planets Around Other Stars: Perform innovative scientific research and technology development by meeting interferometry technology development objectives and by making satisfactory research progress in related R&A programs. (1S7)											X
Search for Life Beyond Earth: Perform innovative scientific research and technology development by meeting technology development objectives and by making satisfactory research progress in the related R&A program, including the Astrobiology program. (1S8)											X
Make Education and Enhanced Public Understanding of Science an Integral Part of our Missions and Research: Continue and expand the integration of education and enhanced public understanding of science with Enterprise research and flight mission programs. (1S9)		X	X	X	X	X	X	X	X	X	X

SSE FY01	**Budget Category**	SIRTF	HST Developmen	GP-B	SOFIA	Payloads	Explorers	Discovery	Mars Surveyor	Operating Missions	SR&T
Investigate the Composition, Evolution, and Resources of Mars, the Moon, and Small Bodies: Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies by successfully launching a Mars mission, by obtaining data from operational spacecraft, and by making satisfactory progress in related R&A and DA programs. (1S10)								X	X	X	X
Develop the Knowledge to Improve the Reliability of Space Weather Forecasting: Develop the knowledge to improve the reliability of space weather forecasting by obtaining scientific data from three of five missions and by making satisfactory progress in related areas in R&A and DA programs. (1S11)										X	X
Develop New Technologies Needed to Carry Out Innovative and Less Costly Mission and Research Concepts: Plan, develop, and validate new technologies needed to enable future research and flight missions by achieving performance objectives in the space science core technology programs and by making progress as planned in the Flight Validation program. (1S12)											X
Living With a Star (New Initiative): Complete Living With a Star Strategic Plan, including mission architecture, for the OSS Strategic Plan, complete a mission definition study, and initiate targeted research and data analysis.											X

Earth Science Enterprise

Mission

The Earth Science Enterprise (ESE) mission is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. The programs of the ESE advance the new discipline of Earth System Science, with a near-term emphasis on global climate change. Both space and ground-based capabilities yield new scientific understanding of Earth and practical benefits to the Nation. The research results will contribute to the development of environmental policy and economic investment decisions. The ESE mission includes the development of innovative technologies to support Earth Science programs and make them available for solving practical societal problems in agriculture and food production, water resources, and national resource management that provide benefits to the Nation. Knowledge and discoveries will be shared with the public to enhance science, mathematics, and technology education as well as increase the scientific and technological literacy of all Americans.

Implementation Strategy

The ESE conducts global and regional research requiring the vantagepoint of space. New programs will be developed and deployed through the "faster, better, cheaper" approach. Program managers are encouraged to accept prudent risk, shorten development time of technologies and missions, explore new conceptual approaches, streamline management, and incorporate innovative methods to enhance efficiency and effectiveness. Programs of the ESE contribute to the U.S. Global Change Research Program (USGCRP) and are conducted in collaboration with ten other U.S. Federal agencies and 13 nations. Cooperative research programs with national and international partners will continue to play a key role in the implementation strategy of the ESE.

The same spirit of innovation that embodies the Earth Science flight programs applies to technology development. Long-term, high-risk, high-payoff technologies are key to implementing the Earth Science mission. The ESE priorities feature near-term product milestones on a path of long-term inquiry. Obtaining data from the private sector is an emerging feature of the ESE strategy. This will reduce Agency costs and encourage the growth of the commercial remote-sensing industry.

ESE's first Science Research Plan, published in 1996, laid out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use changes; short-term climate events, natural hazards research and applications; long-term climate change research; and atmospheric ozone research. The plan also outlined some twenty related areas of research, which underlie these themes and round out the Earth Science contribution to Earth system science. The National Research Council (NRC) recognized the complexity of global Earth environment issues, the multiplicity of interactions between component processes and the cross-disciplinary connections they evoke (Research Pathways for the Next Decade-Overview; NRC, 1998). In the face of such complexity, the NRC outlined a diversity of unsolved scientific questions that call for further study, but also emphasized the need for a focused scientific strategy, concentrating efforts and resources on critical scientific problems that are most relevant to national policy issues. Responding to the latter recommendation, the ESE is pursuing a targeted research program, focused on an updated set of specific science questions that can be addressed effectively with NASA's

capabilities, and formulating comprehensive research strategies that can lead to definitive scientific answers, as well as effective applications for all citizens.

The key research topics studied by NASA's ESE fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth Science program, although it is particularly relevant to the problem of climate change, a major Earth Science-related issues facing the countries of the world. The ESE has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering.

How does the Earth change naturally?

What are the primary forcings of the Earth system by human activities?

How does the Earth system respond to natural and human-induced changes?

What are the consequences of changes in the Earth system for human civilization?

How can we predict the changes in the Earth system that will take place in the future?

These questions will be addressed by a research community organized around science disciplines reflecting Earth system components undergoing and responding to change (e.g. the chemistry of the atmosphere and the biogeochemistry of the global carbon cycle).

Enterprise Resource Requirements

The President has requested the following budget for FY99 to FY05 to support the accomplishment of ESE goals:

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
RY $M	1,414	1,443	1,406	1,333	1,293	1,303	1,306
CS FTE	1,365	1,382	1,419	1,424	1,417	1,431	1,436

Performance Measures

Goal: Expand scientific knowledge by characterizing the Earth system.

Objective: Successfully launch spacecraft.

- Target: The ESE will successfully develop, have ready for launch, and operate instruments on at least two spacecraft within 10 percent of their schedules and budget to enable Earth Science research and applications goals and objectives. 1Y1

Goal: Disseminate information about the Earth system.

Objective: Implement open, distributed, and responsive data system architecture.

The dissemination of information resulting from Earth Science research is accomplished through the Earth Observing System Data and Information System (EOSDIS), and will continue to be a high priority in FY01. Distribution systems will be improved and new methods will be developed to place data in the hands of Earth Science customers in a timely manner through open, distributed, and responsive data system architectures.

Performance target will be to:

- Target: Successfully disseminate Earth Science data to enable our science research and applications goals and objectives. Indicators of this activity will be to increase by 20 percent the volume of climate data archived over the FY00 target of 368 terabytes, increase the number of products delivered from the DAAC archives by 10 percent over FY00, and make the data available to users within five days. 1Y2

Goal: Expand scientific knowledge by characterizing the Earth system.

Objective: Understand the causes and consequences of land-cover/land-use change - determining how land cover and climate changes affect agricultural productivity and terrestrial and marine ecosystem health.

The carbon cycle is one of the major Earth system processes influencing global climate. NASA research on the biology and biogeochemistry of ecosystems and the global carbon cycle aims to understand and predict how terrestrial and marine ecosystems are changing. This research theme addresses ecosystems as they are affected by human activity, as they change due to their own intrinsic biological dynamics, and as they respond to climatic variations and, in turn, affect climate. Emphasis is on understanding

the processes of the Earth system that affect its capacity for biological productivity and the role of the biosphere in Earth system function. Understanding the distribution and cycling of carbon among the active land, ocean, and atmospheric reservoirs constitutes a major scientific focus for research.

The performance targets will be to:

- Target: Explore the dynamics of the global carbon cycle by developing, analyzing, and documenting at least three multi-year data sets. An example of this will be developing a global time series of phytoplankton biomass and primary productivity in the oceans. 1Y3
- Target: Explain the dynamics of global carbon cycle by building improved models and prediction capabilities. One indicator of this activity is improving ecological models needed to predict ecosystem responses to global environmental changes by 15 percent. 1Y4

Objective: Predict seasonal-to-interannual climate variation - determining how water cycles among land, oceans and atmosphere and its impacts on fresh water availability.

Ascertaining the rate of cycling of water in the Earth system, and detecting possible changes, is a first-order problem with regards to the issue of renewal of water resources. Current ESE program activities in this area are; establishing the existence (or absence) of a trend in the rate of the global water cycle, investigating the relationships between large-scale climate anomalies and weather patterns, and accurately representing the integrated effect of water vapor absorption and clouds in a way that is suitable for use in models of climate. The overarching goal is to improve the understanding of the global water cycle to the point at which useful predictions of regional hydrologic regimes can be made. This predictive capability is essential for practical applications to water resource management and for validating scientific advances through the test of real-life prediction.

In FY01 the ESE will continue to invest in observations, research, data analysis, and modeling in this area. The Tropical Rainfall Measuring Mission (TRMM), launched in 1997, will continue to gather information on rainfall in the tropics where two-thirds of global precipitation falls. This is the key to understanding Earth's hydrological cycle, one of the three major processes driving climate change and the global heat balance which drives seasonal change. Current uncertainty in global tropical rainfall estimates is 50 percent; TRMM data will reduce this uncertainty to 10 percent, an 80 percent improvement.

The performance targets will be to:

- Target: Explore the dynamics of global water cycle by developing, analyzing, and documenting at least one multi-year data set such as that needed to obtain accurate maps of the sunrise to sunset changes in precipitation. 1Y5
- Target: Explain the dynamics of global water cycle by building improved models and prediction capabilities, specifically improving current understanding of the large-scale effects of clouds in climate. 1Y6

Objective: Detect long-term climate change, causes, and impacts - understanding, modeling and predicting near and long-term climate variability at global and regional scales.

Climate is not perceived as a static property of the environment any more, but rather a dynamic state that is expected to evolve in the future. This research theme focuses on the modes of variability that involve in a fundamental way the dynamics of the slower components of the physical climate system, the ocean circulation and the mass balance of polar ice sheet. These components respond to disturbances with greater inertia, and therefore longer "memories", than the atmosphere. Currently the ESE research seeks to; understand the mechanisms of climate variability and predict future transient variations, assess the response of the Earth climate to changes in external forcing factors or surface boundary conditions, and assess the current mass balance of polar ice-sheets and potential future changes, including effects on sea level.

The performance targets will be to:

- Target: Explore the dynamics of long term climate variability by developing, analyzing, and documenting at least two multi-year data sets. An example is continuing the high precision, multi-decadal record of total solar irradiance, providing a quantitative understanding of the solar forcing effects on Earth's climate. 1Y7
- Target: Explain the dynamics of long term climate variability by building improved models and prediction capabilities. One example of this activity will be demonstrating experimental seasonal climate predictions by using next generation super computing systems and new-coupled air-ocean-land-ice models. 1Y8

Objective: Understand the causes of variation in atmospheric ozone concentration and distribution - monitoring and predicting how atmospheric composition is changing in response to natural and human-induced factors.

Atmospheric change is the result of strongly interactive chemical and physical processes. Chemistry plays a role in determining weather and climate, while the physics and dynamics of the atmosphere influence chemical processes and composition. The goals of the Atmospheric Chemistry Research Program are to measure and understand how atmospheric composition is changing in response to natural and anthropogenic forcings, and enable accurate prediction of future changes in ozone and surface ultraviolet radiation, climate forcing factors, and global pollution.

The performance targets will be to:

- Target: Explore the dynamics of atmospheric composition by developing, analyzing, and documenting at least three multi-year data sets, such as providing continuity of multi-decadal total ozone concentration measurements. 1Y9
- Target: Explain the dynamics of atmospheric chemistry by building improved models and prediction capabilities. One example of this activity will be characterizing the atmospheric plume flowing out of East Asia, its evolution as it transits eastward over the Pacific, and its contribution to global atmospheric chemical composition. 1Y10

Objective: Identify natural hazards, processes, and mitigation strategies - discovering the nature and processes of the Earth's dynamic interior and crust to better prepare for natural hazards.

The long-standing Earth Science Research Program in fundamental solid Earth Science explores issues such as the dynamics of the Earth's interior and crust, tectonic motions, earthquakes, volcanic eruptions, and the evolution of landscapes. Results of this and other relevant activities are developed and applied to the assessment and mitigation of natural disasters for the practice of disaster management, working together with practitioners at the international, federal, state and local levels. Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of observational capabilities and techniques which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

The ESE will use a combination of space-based and airborne assets to monitor and assess impacts of natural hazards such as volcanoes, earthquakes, forest fires, hurricanes, floods and droughts. The short-term objective is to assess impacts of these events on national and international agriculture, food production, water resources, commerce, etc. The long-term objective is to apply the scientific understanding toward developing a predictive capability.

In FY01 the ESE will continue to provide the technology and instruments to allow collection of interferometric Synthetic Aperture Radar (SAR) data. This will enable the first consistent global topography data record collected from space, and will have a variety of applications including flood hazard assessment, laying out new roadways and pipelines, and providing airline operators with detailed elevation data for remote areas.

The performance targets will be to:

- Target: Explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting at least one multi-year data set such as analysis of 30 meter topographic data for global geological and geomorphic process studies and improved mapping of terrain features. 1Y11
- Target 1Y12: Explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. An indicator of this activity will be providing a basis for future tectonic modeling and earthquake vulnerability assessment through completion of the Southern California Integrated GPS network. 1Y12

Goal: Enable the productive use of ESE science and technology in the public and private sector.

Objective: Develop and transfer advanced remote sensing technologies.

In collaboration with partners in industry and academia, the ESE will develop and demonstrate new technologies of value to remote-sensing research.

The performance target will be to:

- Target: Achieve success in timely development and infusion of technologies. This will be accomplished by formal technology readiness assessment of critical technology essential for implementing proposed mission concepts. The Technology Readiness levels (TRLs) will be such that the mission development cycle can be accomplished within a 3-year cycle. This activity will enable future science missions by increasing technology readiness for mission concepts to reduce their total cost. An example indicator is the transfer at least one technology development to a commercial entity for operational use. 1Y13

Objective: Extend the use of Earth Science research for national, state, and local applications.

Because the ESE addresses science questions of societal importance, the research performed also leads to practical applications. ESE works with National, State, and local government entities to help them develop remote sensing applications products to address issues of importance to them. These include agricultural productivity, natural resources management, as well as urban and regional planning.

The performance targets will be to:

- Target: Provide regional decision-makers with scientific and applications products/tools. An example indicator is an effort with USGS, to produce a new Landsat-7 based map of each of the 50 states for their use in communicating geographic information. 1Y14
- Target: Improve access to and understanding of remotely sensed data and processing technology. An example indicator is putting on informational workshops in using Earth Science observations and information involving at least 20 states. 1Y15

Objective: Support the development of a robust commercial remote sensing industry.

NASA is committed to a growing relationship with the commercial remote sensing industry to enhance the utility of Earth Science information in the U.S. economy. Commercial firms are both potential sources of science-quality remote sensing data, and producers of "value-added" information products from U.S. research satellites.

The performance targets will be:

- Target: Stimulate the development of a robust commercial remote sensing industry. An example indicator is developing ten new commercial products in joint commercial applications research projects. 1Y16
- Target: Increase efficiencies in food and fiber production with the aid of remote sensing by conducting at least 20 joint applications research endeavors in conjunction with the U.S. Department of Agriculture. 1Y17

Objective: Increase public understanding of Earth System through education and outreach.

Earth Science missions and research programs make a unique contribution to education and the public understanding of Earth Science. They provide a steady return of discoveries and new knowledge contributes to the accomplishment of this objective. The ESE will continue to sponsor research awards through NASA's Graduate Student Research Program.

The performance target will be to:

- Target: Increase public understanding of Earth system science through formal and informal education. The ESE will continue and improve upon prior year performance in the areas of graduate research and education grants, K-12 teacher workshops, and participation in GLOBE. 1Y18

Objective: Make major scientific contributions to national and international environmental assessments.

Because of the nature of the discipline, it is vital that Earth Science research be conducted through cooperation and partnerships with other agencies and with other countries. The ESE will continue to contribute scientific knowledge and observations and modeling results to national and international scientific environmental assessments. The targets for this objective are embedded within targets in other program areas.

Internal Assessment

The Earth Science Enterprise will regularly review performance objectives as part of our existing monthly review process. Using a database to track current performance monthly for each specific FY01 target will enable the Enterprise to focus on targets that need improvement. ESE management will institute measures to ensure improvement.

As ESE is a scientific endeavor, many of its measures involve scientific results. These are subject to peer review, both in the selection of the science investigation, and in the reporting of findings in the scientific literature. Where the metric is production of a data product, these must be archived in ESE's information system, where their availability can be confirmed via an Internet query. Metrics addressing scientific assessment activities result in formal, published reports that are readily identified.

External Assessment

The Earth Science Advisory Committee of the NASA Advisory Council will conduct an annual assessment of the ESE's near-term science objectives. The Committee will provide a qualitative progress measurement (Green, Yellow, or Red). "Green" will indicate that the objective was met; "Yellow" will indicate a concern that an objective was not fully accomplished; and "Red" will indicate that events occurred that prevented or severely impaired the accomplishment of the objective. The assessment will include commentary to clarify and supplement the qualitative measures.

Earth Systems Science and Application Advisory Committee (ESSAAC) is a committee of the NASA Advisory Council under the Federal Advisory Committee Act, and comprises outside scientific and technical experts from academia, industry, and other government agencies. ESSAAC meets at least twice a year to review plans and progress in the ESE. After the end of each fiscal year, the ESE will provide ESSAAC a self-assessment in each of the relevant objectives, highlighting performance against the metrics in the Performance Plan for that year. ESSAAC will deliberate internally and render its own assessment, which may confirm or modify the ESE's self-assessment. ESSAAC's assessment will be reported in the Performance Report for that year. This process will be repeated annually.

Earth Science FY01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01 #	FY01 Targets	FY01 Indicators
Expand scientific knowledge by characterizing the Earth system.	**Successfully launch spacecraft**	*1Y1*	Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives.	Accomplish target within 10% of schedule and budget. At least 90% of the on-orbit instrument complement fully operational.
Disseminate information about the Earth system.	**Implement open, distributed, and responsive data system architecture.**	*1Y2*	Successfully disseminate Earth Science data to enable our science research and applications goals and objectives.	Increase by 20% the volume of climate data archived, increase the number of products delivered from the DAAC archives by 10%, and make available acquired observations and resulting information to users within 5 days of acquisition.
Expand scientific knowledge by characterizing the Earth system.	**Understand the causes and consequences of land-cover/land-use change.**	*1Y3*	Explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets.	Develop, analyze, and document at least three multi-year data sets.
		1Y4	Explain the dynamics of global carbon cycle by building improved models and prediction capabilities.	Improve by at least 15% the ecological models and provide information to understand remotely sensed observations.
	Predict seasonal-to-interannual climate variations.	1Y5	Explore the dynamics of global water cycle by developing, analyzing, and documenting multi-year data sets.	Develop, analyze, and document at least one multi-year data sets. Decrease the uncertainty by at least 20% in determinations of radiation forcing and feedback.
		1Y6	Explain the dynamics of global water cycle by building improved models and prediction capabilities.	Complete collection and processing of satellite data needed for the multi-decadal global cloud climatology, validate parameterizations of Earth's radiative processes, and demonstrate the capability to measure and diagnose soil moisture remotely from airborne platforms.
	Detect long-term climate change, causes, and impacts.	*1Y7*	Explore the dynamics of long term climate variability by developing, analyzing, and documenting multi-year data sets.	Develop, analyze, and document at least three multi-year data sets.
		1Y8	Explain the dynamics of long term climate variability by building improved models and prediction capabilities.	Develop and demonstrate the capability to measure and diagnose open ocean variations in salinity by 0.1 psu. Develop and validate aerosol retrieval and cloud screening algorithms, and processing of satellite data and transport model evaluations. Demonstrate the experimental seasonal climate predictions.
	Understand the causes of variation in atmospheric ozone concentration and distribution.	1Y9	Explore the dynamics of atmospheric composition by developing, analyzing, and documenting multi-year data sets.	Develop, analyze, and document at least three multi-year data sets.

Earth Science FY01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01 #	FY01 Targets	FY01 Indicators
		1Y10	Explain the dynamics of atmospheric chemistry by building improved models and prediction capabilities.	Provide increased prognostic ability for Northern hemisphere high latitude ozone loss, develop the first global climatology of carbon monoxide and total column methane, and characterize atmospheric plume flowing out of East Asia, its evolution, and its contribution to global atmospheric chemical composition.
	Identify natural hazards, processes, and mitigation strategies.	1Y11	Explore dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets.	Develop, analyze, and document at least one multi-year data set.
		1Y12	Explain dynamics of the Earth's interior and crust by building improved models and prediction capabilities.	Improve understanding of geodynamic processes, allow continuous observations, improved data processing efficiency, and reduce operational costs by 20%. Provide a basis for future tectonic modeling and earthquake vulnerability assessment.
Enable the productive use of ESE science and technology in the public and private sectors.	**Develop and transfer advanced remote-sensing technologies.**	1Y13a-c	***Achieve success in timely development and infusion of technologies.*** Enable future science missions by increasing technology readiness for mission concepts to reduce their total cost.	Advance at least 25% of funded instrument technology developments one Technology readiness level (a). Develop advanced information systems technologies and concepts (b). Develop at least 3 technologies to demonstrate them in space with the third Earth Observer New Millennium satellite (c). Transfer at least one technology development to a commercial entity for operational use.
	Extend the use of Earth science research to regional, state, and local applications.	1Y14	Provide regional decision-makers with scientific and applications products/tools.	Establish at least a second Regional Earth Science Application Center (RESAC) as a self-sustaining entity. Produce a digital image database of all 50 states once every two years. Develop capability to assess the vulnerability of fishing grounds due to water quality issues. Develop experimental models to demonstrate an ability to improve forecast skill levels. Monitor and predict the track of at least one key atmospheric pollutant species. Develop a prototype air quality assessment. Initiate two Applications Research projects with the public and private sector. Develop a predictive capability for outbreaks of malaria with 50% accuracy in Central Africa. Develop at least two new data products for routine decision-making.
		1Y15	Improve access to and understanding of remotely sensed data and processing technology.	Involve at least 20 states in informational workshops to foster applications of remote sensing data and processing technology. Initiate at least 10 joint Application Research pilot projects. Implement at least 10 active student internships at the State and local level.

Earth Science FY01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01 #	FY01 Targets	FY01 Indicators
	Support the development of a robust commercial remote sensing industry.	1Y16a	Stimulate the development of a robust commercial remote sensing industry.	Develop 10 new market commercial products. Identify at least one new commercial source of science. Develop 4 new validated commercial information products. Provide 10 prototype products that quantify the utility of Hyperspectral and Synthetic Aperture Radar (SAR) technologies and define future market requirements. Increase cost share leveraging with companies, academia, and other government agencies by 10%.
		1Y17	Increase efficiencies in food and fiber production with the aid of remote sensing.	Conduct at least 30 joint applications research endeavors in conjunction with the U.S. Dept of Agriculture
	Increase public understanding of earth system science through education and outreach.	1Y18	Increase public understanding of Earth system science through formal and informal education.	Continue 90 existing grants and award 50 new graduate student research and education grants. Continue 17 early career grants in research/education and initiate at least two new collaborative projects. Conduct at least 400 workshops training K-12 teachers. Increase participating teachers in Global Learning and Observation to Benefit the Environment (GLOBE) to 13,800 and increase participating countries to 87.

ESE FY01	Budget Category	EOS	Earth probes	Operations	Research and Technology
Performance Target					
Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives. (1Y1)		X	X	X	
Successfully disseminate Earth Science data to enable our science research and applications goals and objectives. (1Y2)		X			
Explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets. (1Y3)		X	X	X	X
Explain the dynamics of global carbon cycle by building improved models and prediction capabilities. (1Y4)		X			X
Explore the dynamics of global water cycle by developing, analyzing, and documenting multi-year data sets. (1Y5)		X		X	X
Explain the dynamics of global water cycle by building improved models and prediction capabilities. (1Y6)		X			X
Explore the dynamics of long term climate variability by developing, analyzing, and documenting multi-year data sets. (1Y7)		X			X
Explain the dynamics of long term climate variability by building improved models and prediction capabilities. (1Y8)		X		X	X
Explore the dynamics of atmospheric composition by developing, analyzing, and documenting multi-year data sets. (1Y9)		X	X	X	X
Explain the dynamics of atmospheric chemistry by building improved models and prediction capabilities. (1Y10)		X			X
Explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets. (1Y11)					X

ESE FY01	**Budget Category**	EOS	Earth probes	Operations	Research and Technology
Explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities. (1Y12)					X
Achieve success with timely development and infusion of technologies. Enable future science missions by increasing technology readiness for mission concepts to reduce their total cost. (1Y13)					X
Provide regional decision-makers with scientific and applications products. (1Y14)		X		X	X
Improve access to and understanding of remotely sensed data and processing technology. (1Y15)					X
(1Y16)					X
sensing. (1Y17)					X
Increase public understanding of Earth system science through formal and informal education. (1Y18)					X

Human Exploration and Development of Space

Mission

The Human Exploration and Development of Space (HEDS) Enterprise mission is to open the space frontier by exploring, using, and enabling the development of space to expand the human experience into space and bring the benefits of space to Earth. The Enterprise mission includes the development of innovative technologies to support HEDS programs and make them available for other applications that provide benefits to the Nation. Knowledge and discoveries will be shared with the public to enhance science, mathematics, and technology education and increase the scientific and technological literacy of all Americans.

Implementation Strategy

The HEDS Enterprise strategy is integrated and implemented by two program offices: the Office of Space Flight (OSF) and the Office of Life and Microgravity Sciences and Applications (OLMSA).

The OSF strategy to contribute to the HEDS mission is focused on providing the infrastructure to enable research, exploration, and development, and consists of four major components: ensure safe, reliable and affordable access to space; establish permanent human presence aboard an earth-orbiting research laboratory; provide a space operations infrastructure; and expand the commercial development of space. To ensure safe, reliable and affordable access to space, safety investments provide for the modifications and improvements of the Space Shuttle and ground facilities through replacement of obsolete systems and expansion of safety and operating margins. Investments are also made in Space Shuttle operations including hardware production, ground and payload processing, launch and landing operations, flight crew operations, training, logistics, sustaining engineering, and in support of agency-wide needs for expendable launch vehicle (ELV) services. The implementation strategy for establishing permanent human presence in space is encompassed in the International Space Station (ISS) program. Assembly began with the November 1998 launch of the U.S.-owned/ Russian-launched functional cargo block (FGB) and permanent human presence should begin this year, as assembly continues. A space operations infrastructure that supports agency-wide operations is provided, and innovative approaches to expanding the commercial development of space are being pursued.

The OLMSA strategy to contribute to the HEDS mission is focused on conducting three types of research and technology development: fundamental, mission-driven, and application-driven research. OLMSA supports fundamental research driven by an emphasis on expanding scientific knowledge. Its focus on mission-driven research improves knowledge and technology for human space flight. The application-driven research of OLMSA seeks to transfer knowledge, expertise, and technology from HEDS missions to other uses that provide benefits to the Nation.

Enterprise Resource Requirements

The President has requested the following budget for FY99 to FY05 to support the accomplishment of HEDS goals:

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
RY$M	5,744	5,742	5,802	5,688	5,243	5,141	5,012
CS FTE	5,364	5,294	5,627	5,539	5,382	5,170	4,967

Performance Measures

Goal: Expand the Space Frontier.

Objective: Expand human exploration through collaborative robotic missions

- Target: Complete testing and delivery for spacecraft integration of experiments for the Mars Surveyor Program 2001 orbiter and lander missions. HEDS research planned for the mission includes radiation monitoring, soil and dust analysis, and an experiment on the production of propellants from the Martian atmosphere. 1H1

Objective: Define innovative human exploration mission approaches

- Target: Complete initial next decade planning mission architecture studies and technology plans. Architecture studies support near-term technology investment decisions to create building blocks that may enable a range of long-term planning options for future missions of exploration. 1H2

Objective: Invest in enabling high-leverage technologies

- Target: Initiate the HEDS Technology/Commercialization program and establish a synergistic relationship with industry. Indicator is a successful response to the initial NASA Research Announcement, with a 50% cost share from industry, where appropriate. 1H32

Goal: Expand Scientific Knowledge.

Objective - In partnership with the scientific community, use the space environment to investigate chemical, biological and physical systems.

- Target: Support an expanded, productive research community to include 975 investigations annually by 2001. HEDS seeks to prepare and support a research community to take full advantage of research opportunities in the coming era of orbital research, including support for 975 investigations in 2001. 1H3

- Target: Conduct outstanding peer-reviewed and commercial research on STS 107 to advance knowledge in the fields of medicine, fundamental biology, biotechnology, fluid physics, materials processing and combustion. 1H4

- Target: Begin research on the International Space Station. HEDS will increase fundamental knowledge and address critical questions in crew health and safety by conducting six to ten investigations on the International Space Station. Other investigations will include research on the behavior of colloids as a first step in the synthesis of new materials from colloidal particles, and detailed measures of the acceleration environment on ISS for use in planning future research. 1H5

Goal: Enable and establish a permanent and productive human presence in Earth orbit.

Objective: Provide safe and affordable access to space.

- Target: The Office of Space Flight will expedite a safety improvement program to ensure the continued safe operations of the Space Shuttle. The performance target is to have in place a Shuttle upgrade program that ensures the availability of a safe and reliable Shuttle system to support Space Station Assembly milestones and operations. The FY 2001 indicators include completion of the Checkout and Launch Control System applications software for the Orbiter Processing Facilities. All safety improvements are planned to be in place by 2005. 1H6

- Target: The Office of Space Flight continues to invest in Space Shuttle operations. Investments include hardware production, ground processing, launch and landing operations, flight crew operations, training, logistics, and sustaining engineering. The performance target is to achieve 8 or fewer flight anomalies per mission. 1H7

  The Shuttle program uses safety/reliability and stability/schedule indicators. The Space Flight Operations Contractor, United Space Alliance, is subject first to an incentive safety/reliability gate, after which come various stability/schedule indicators like the one presented here. The FY 2001 indicator is to measure (post flight) the number of vehicle flight anomalies.

- Target: Achieve 100% on-orbit mission success. This target will be measured against the customer's mission objectives and the post-flight reporting of completion of mission objectives. 1H30

Objective: Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives

- Target: Development, manufacture and test of the ISS vehicle elements are phased in conjunction with the launch and on-orbit assembly schedule. The performance target is to successfully complete the majority of the planned development schedules and milestones required to support the Multi-element Integration Testing (MEIT). 1H10

  MEIT tests perform integration testing with several launch elements to increase on-orbit confidence. The FY 01 indicator will include completion of MEIT to include flight elements for assembly flights 8A through 12A. This will be measured by completion of five-planned test configurations.

- Target: Deployment of the ISS occurs with on-orbit assembly over several years. Successful and timely deployment is dependent on the Shuttle and other international launch vehicles, and the provision of some elements and services from international partners and participants. The performance target is to successfully complete the majority of the ISS planned on-orbit activities such as delivery of mass to orbit and enhanced functionality. 1H11

  FY01 indicators will include expansion of the capabilities of the ISS through launch and delivery of 180,000 lbs. of hardware and logistics to the ISS; and initiation and demonstration of ISS Extravehicular Activity (EVA) capability to support up to 30 EVAs annually from the U.S. Airlock. This will be measured by completion of a minimum of 5 EVAs from the ISS Airlock.

- Target: Operations of the ISS occur as the vehicle is being developed and assembled. The performance target to successfully complete the majority of combined ISS planned operations schedules and milestones as represented by permanent human on-orbit operations. 1H12

  FY01 Indicators will include the presence of permanent human on-orbit operations with an estimated 8,000 crew hours dedicated to assembly, vehicle operations and payload operation.

- Target: The conduct of research is an important objective of the ISS. During assembly, the ISS will add pressurized volume, experiment racks, facilities and unpressurized payload accommodations in support of research opportunities. The performance target is to successfully complete the majority of the planned research activities in support of initiation of on-orbit research opportunities. 1H13

  FY 01 Indicators will include initiation of on-orbit research in the U.S. Laboratory focusing on early payload opportunities in the Human Research Facility (HRF-1) and multipurpose EXPRESS Racks.

- Target: The ISS program has undertaken a series of selected developments and support activities to enhance the robustness of the vehicle, enhance safety and reduce reliance on capabilities contributed by Russia. The performance target is to successfully complete no less than 85% of the planned Russian Program Assurance schedules and milestones required for the development of the Propulsion Module. 1H14

  FY01 indicators will include initiation of Propulsion Module fabrication/assembly/integration and testing in preparation for launch in late FY 2002. This will be measured by completion of schedule milestones.

- Target: Crew transportation and return for up to three crewmembers is planned to be provided by Russia throughout the life of the program. In order to further enhance ISS safety, NASA has initiated the Phase 1 development of a crew return vehicle (CRV) that could provide the U.S. crew return capability to support the emergency return of up to seven crew, the full crew complement planned for the ISS. A U.S. crew return capability is planned for deployment late in the ISS assembly sequence. The performance target is to successfully complete no less than 75% of the planned crew return capability schedules. FY01 indicators will include accomplishment of program schedule milestones for Phase 1 development of a crew return vehicle (CRV) that could provide the U.S. crew return capability. 1H15

Objective: Ensure the health, safety and performance of humans living and working in space

- Target: Develop new biomedical and technological capabilities to facilitate living and working in space and return to Earth. HEDS will flight test a new method for reducing the risk of kidney stone formation and develop two new evidence-based countermeasure candidates ready for evaluation. 1H17

- Target: Develop and demonstrate technologies for improved life support systems. HEDS will demonstrate, in ground test, technologies that could reduce up to 25% of life support logistics over ISS baseline as determined by the detailed calculation of a life support equivalent system mass index and place online for review and comment. Equivalent system mass index is a measure of the performance of a life support system incorporating demonstrated technologies. Performance improves as improved technologies are demonstrated. 1H18

- Target: Initiate implementation of the Bioastronautics Initiative. The bioastronauctics initiative will enhance activities already underway in order to ensure the health, safety, and performance of humans in space by accelerating research and development of "countermeasures" (diagnostics, therapy, preventatives, and rehabilitation methods) to maintain the health of flight crews on long duration missions and transfer this knowledge and technology to benefit health on Earth. Bioastronautics research is an interdisciplinary set of focused research activities bringing together biology, physics, chemistry, communications technology and nano-technologies that will revolutionize medical care delivery in space and on Earth. Indicators for FY 01 will include initiating a NASA/NCI collaboration to develop minimally invasive technologies and approaches for detecting and interpreting biological signatures that signal the emergence of disease. 1H31

Objective: Meet sustained space operations needs while reducing costs.

- Target: Increase the percentage of the space operations budget allocated to acquisition of communications and data services from the commercial sector to 15% in FY 2001. The space Communications Program will conduct tasks that enable commercialization and will minimize investment in government infrastructure for which commercial alternatives are being developed. 1H20

- Target: Achieve at least 95 percent of planned data delivery from space flight missions as documented in space, ground, deep space, and NASA integrated service networks performance metrics consistent with detailed program and project operations requirements in project service level agreements. 1H21

Goal: Expand the Commercial Development of Space.

Objective: Facilitate access to space for commercial researchers.

- Target: Establish at least ten new, active industrial partnerships to research tomorrow's space products and improve industrial processes through NASA's Commercial Centers, and find opportunities for space experiments. 1H22

Objective: Foster commercial participation on the International Space Station.

- Target: Foster commercial endeavors by reviewing and/or implementing new policies and plans, such as the Space Station resource pricing policy and intellectual property rights policy. Ensure that Space Station resources allocated to commercial research are utilized by commercial partners to develop commercial products and improve industrial processes. 1H23

Goal: Share the Experience and Discovery of human space flight

Objective: Increase the scientific, technological and academic achievement of the nation by sharing our knowledge, capabilities, and assets.

- Target: Support participation in HEDS research. In 2001 HEDS will enable at least 50 students to participate in commercial space flight and technologies research and provide 200 elementary and high school classrooms nationwide with electronic (multimedia/computer technologies) and printed materials that focus on activities in science, math and technology relating to life sciences and microgravity research and specifically written for students in grades K-12. In addition HEDS will complete a broadly based student competition on innovative design concepts that address HEDS technological challenges and complete a customer engagement plan. 1H26

Cross-cutting target

- Target: Improve health of the NASA workforce. HEDS will develop and implement supervisor-specific training for the identification and management of stress in the work unit. Develop and implement training on techniques for coping with stress for the individual employee and begin a robust audit program of NASA Centers' occupational health programs, completing at least six (6) to ensure quality and continuous improvement of medical care and services including medical and environmental monitoring efforts, preventive services, emergency response capability, and clinical intervention capability. 1H29

Internal Assessment

Interim evaluation and monitoring of performance targets will be conducted as an element of regular meetings of the Office of Space Flight and HEDS Management Boards and the Board of Directors of the Office of Life and Microgravity Sciences and Applications. As a matter of NASA policy, relevant HEDS performance targets are included in the performance plans submitted to the Administrator by the Associate Administrator of the Office of Life and Microgravity Sciences and Applications, and the Associate Administrator of the Office of Space Flight.

Final data collection, reporting and verification for inclusion in the Annual Performance Report will rely on several different processes depending on the particular Performance Target. Wherever possible, a specific tangible product has been identified for individual performance targets to strengthen the validation process.

For many HEDS performance targets, (e.g. Space Shuttle in-flight anomalies, Space Station assembly milestones) verification of performance is straightforward and progress is monitored through regular management channels and reports. For targets which include references, investigators and/or peer reviewed publications, HEDS publishes, and makes available on line, an annual "Task Book and Bibliography" which includes lists of investigators, publications and research results. This database will be an essential source of data for evaluating performance against several targets.

External Assessment

To assist in evaluating those performance goals which are more difficult to associate with specific tangible products, HEDS will employ an annual external assessment process. HEDS has asked the Life and Microgravity Sciences and Applications subcommittee of the NASA Advisory Committee to review and evaluate performance on specific OLMSA targets an on an annual basis. An OSF Advisory Committee currently being formed will review and evaluate OSF performance targets.

Human Exploration and Development of Space FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01#**	**FY 01 Target**	**FY 01 Indicators**
Goal: Expand the Space Frontier.	Objective: Expand human exploration through collaborative robotic missions	1H1	Complete testing and delivery for spacecraft integration of experiments for the Mars Surveyor Program 2001 orbiter and lander missions.	Complete testing and delivery for spacecraft integration for the radiation monitoring experiment hardware (MARIE). Complete testing and delivery for spacecraft integration for the soil and dust analysis experiment (MECA). Complete testing and delivery for spacecraft integration for the Mars In-Situ Propellant Production Precursor experiment (MIP) .
Goal: Expand the Space Frontier.	Objective: Define innovative human exploration mission approaches	1H2	Complete initial next decade planning mission architecture studies.	Complete initial next decade planning mission architecture studies.
Goal: Expand the Space Frontier.	Invest in enabling high-leverage technologies	1H32	Initiate the HEDS Technology/Commercialization program and establish a synergistic relationship with industry.	Indicator is a successful response to the initial NASA Research Announcement, with a 50% cost share from industry, where appropriate.
Goal: Expand Scientific Knowledge.	Objective - In partnership with the scientific community, use the space environment to investigate chemical, biological and physical systems.	1H3	Support an expanded, productive research community to include 975 investigations by 2001.	Expand support to approximately 975 investigations (from 877 reported in FY 99). Publish abstracts and reports of progress for over 90% of FY 2000 research investigations (tasks) and make this publication available on the internet. Support publication of approximately 1500 journal articles in refereed journals. Support emergent microgravity research programs in biophysics and tissue engineering by selecting up to 10 new investigations.
Goal: Expand Scientific Knowledge.	Objective - In partnership with the scientific community, use the space environment to investigate chemical, biological and physical systems.	1H4	Conduct outstanding peer-reviewed and commercial research on STS 107 to advance knowledge in the fields of medicine, fundamental biology, biotechnology, fluid physics, materials processing and combustion.	Acquire unique data to improve crew health and safety and expand understanding in biology, biotechnology cell science, fluid physics, and combustion science.

Human Exploration and Development of Space FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01#**	**FY 01 Target**	**FY 01 Indicators**
Goal: Expand Scientific Knowledge.	Objective - In partnership with the scientific community, use the space environment to investigate chemical, biological and physical systems.	1H5	Begin research on the International Space Station.	Increase fundamental knowledge in biological and biomedical sciences and address critical questions in crew health and safety by conducting 6 to 10 ISS investigations. Acquire unique data on colloidal self-assembly as an essential first step in the synthesis of new materials from colloidal particles. Measure the ISS acceleration environment, develop models to characterize the effects of that environment on ISS research, and disseminate those results to the ISS investigator community.
Enable and establish a permanent and productive human presence in Earth orbit.	Provide safe and affordable access to space.	1H6	The Office of Space Flight will expedite a safety improvement program to ensure the continued safe operations of the Space Shuttle that ensures the availability of a safe and reliable Shuttle system to support Space Station Assembly milestones and operations.	CLCS application for the Orbiter Processing Facilities is completed.
Enable and establish a permanent and productive human presence in Earth orbit.	Provide safe and affordable access to space.	1H7	Achieve 8 or fewer flight anomalies per mission.	Achieve 8 or fewer flight anomalies per mission.
Enable and establish a permanent and productive human presence in Earth orbit.	Provide safe and affordable access to space.	1H30	Achieve 100% on-orbit mission success.	Pre-flight mission/payload objective. Post-flight mission report.
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives	1H10	Successfully complete the majority of the planned development schedules and milestones required to support the Multi-element Integration Testing.	Complete Multi-Element Integration Test II (MEIT) to include flight elements for assembly flights 8A through 12A. This will be measured by completion of five-planned test configurations. MEIT Tests perform integration testing with several launch elements to increase on-orbit confidence.
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives	1H11	Successfully complete the majority of the ISS planned on-orbit activities such as delivery of mass to orbit and enhanced functionality.	Continue to expand the capabilities of the ISS through launch and delivery of 180,000 lbs. of hardware and logistics to the ISS. Initiate and demonstrate station-based Extravehicular Activity (EVA) capability to support up to 30 EVAs annually from the U.S. Airlock. This will be measured by completion of a minimum of 5 EVAs from the ISS Airlock.

Human Exploration and Development of Space FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01#**	**FY 01 Target**	**FY 01 Indicators**
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives	1H12	Successfully complete the majority of combined ISS planned operations schedules and milestones as represented by permanent human on-orbit operations.	Conduct permanent human on-orbit operations with an estimated 8,000 crew hours dedicated to assembly, vehicle operations and payload operations.
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives	1H13	Successfully complete the majority of the planned research activities in support of initiation of on-orbit research opportunities.	Initiate on-orbit research in the U.S. Laboratory focusing on early payload opportunities in the Human Research Facility (HRF-1) and four multipurpose EXPRESS Racks. Complete integration testing and KSC processing for the Microgravity Sciences Glovebox (MSG), refrigerator/freezer, and Window Observational Research Facility (WORF-1) in preparation for launch on UF-1 and UF-2. This will be measured by completion of schedule milestones.
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives Ensure and enhance the health, safety, & performance of humans in space	1H14	Successfully complete no less than 85% of the planned Russian Program Assurance schedules and milestones required for the development of the Propulsion Module.	Initiate Propulsion Module Fabrication/Assembly/Integration and Testing in preparation for launch in late FY 2002. This will be measured by completion of schedule milestones.
Enable and establish a permanent and productive human presence in Earth orbit	Deploy and use the ISS to advance scientific, exploration, engineering, and commercial objectives Ensure and enhance the health, safety, & performance of humans in space	1H15	Successfully complete no less than 75% of the planned crew return capability schedules. FY01 indicators will include accomplishment of program schedule milestones for Phase 1 development of a crew return vehicle that could provide U.S. crew return capability.	Complete Crew Return Vehicle (CRV) Phase 1 tasks including Preliminary Design Review (PDR). This will be measured by completion of schedule milestones.

Human Exploration and Development of Space FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01#**	**FY 01 Target**	**FY 01 Indicators**
Enable and establish a permanent and productive human presence in Earth orbit	Objective: Ensure the health, safety and performance of humans living and working in space	1H17	Develop new biomedical and technological capabilities to facilitate living and working in space and the safe return to Earth.	Flight test countermeasure to reduce kidney stone risk . Develop two new evidence-based health protective countermeasure candidates ready for evaluation in an operational setting.
Enable and establish a permanent and productive human presence in Earth orbit	Objective: Ensure the health, safety and performance of humans living and working in space	1H18	Develop and demonstrate technologies for improved life support systems.	Demonstrate, in ground test, technologies that could reduce up to 25% of life support logistics over ISS baseline and release report of progress for review on the internet. Perform detailed calculation of life support equivalent system mass index and place online for review and comment. Equivalent system mass index is a measure of the performance of a life support system incorporating demonstrated technologies.
Enable and establish a permanent and productive human presence in Earth orbit	Objective: Ensure the health, safety and performance of humans living and working in space	1H31	Initiate implementation of the Bioastronautics Initiative.	Initiate NASA/NCI collaboration to develop minimally invasive technologies and approaches for detecting and interpreting biological signatures that signal the emergence of disease. Initiate expansion of the teams and tasks of the NSBRI for the development of countermeasures, by adding approximately 15 investigations (tasks).
Enable and establish a permanent and productive human presence in Earth orbit.	Meet sustained space operations needs while reducing costs.	1H20	Increase the percentage of the space operations budget allocated to acquisition of communications and data services from the commercial sector to 15%.	Increase to 15% the space operations budget allocated to acquisition of commercial communications and data services from the 10% FY 2000 performance target.
Enable and establish a permanent and productive human presence in Earth orbit.	Meet sustained space operations needs while reducing costs.	1H21	Achieve at least 95 percent of planned data delivery, on average, from space flight missions as documented in space, ground, deep space, and NASA integrated service networks performance metrics consistent with detailed program and project operations requirements in project service level agreements.	Achieve at least 95 percent data delivery for all space flight missions as documented in network performance metrics.
Goal: Expand the Commercial Development of Space.	Facilitate access to space for commercial researchers	1H22	Establish at least ten new, active industrial partnerships to research tomorrow's space products and improve industrial processes through NASA's Commercial Centers and find opportunities for space experiments.	Ensure that Commercial Centers execute ten new partnership agreements. Monitor the ratio of flight experiments to ground experiments.

Human Exploration and Development of Space FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01#**	**FY 01 Target**	**FY 01 Indicators**
Goal: Expand the Commercial Development of Space.	Foster commercial participation on the International Space Station.	1H23	Foster commercial endeavors by reviewing and/or implementing new policies and plans, such as the Space Station resource pricing policy and intellectual property rights policy. Ensure that Space Station resources allocated to commercial research are utilized by commercial partners to develop commercial products and improve industrial processes.	Review and/or implementing Space Station resource pricing and intellectual property rights policies. Ensure Space Station resources allocated to commercial research are utilized by commercial partners to research tomorrow's products and improve industrial processes.
Goal: Share the Experience and Discovery of human space flight	Increase the scientific, technological and academic achievement of the nation by sharing our knowledge, capabilities, and assets	1H26	Support participation in HEDS research.	Enable at least 50 students to participate in commercial space flight and technologies research. Through the use of national teacher conferences and workshops, provide approximately 200 elementary and high school classrooms nationwide with electronic (multimedia/computer technologies) and printed materials that focus on activities in science, math and technology relating to life sciences and microgravity research and specifically written for students in grades K-12. Complete a broadly based student competition on innovative design concepts that address HEDS technological challenges. Complete customer engagement plan.
Cross-cutting target		1H29	Improve health of the NASA workforce	Develop and implement supervisor-specific training for the identification and management of stress in the work unit. Develop and implement training on techniques for coping with stress for the individual employee. Begin a robust audit program of NASA Centers' occupational health programs, completing at least six (6) to ensure quality and continuous improvement of medical care and services including medical and environmental monitoring efforts, preventive services, emergency response capability, and clinical intervention capability.

HEDS FY01	Budget Category	Space Station	Space Shuttle	Paylaod and ELV Support	Space Operations	Life and Microgravity Sciences	HEDS Investments	Research and Program Management
Performance Target								
1H1: Complete testing and delivery for spacecraft integration of experiments for the Mars Surveyor Program 2001 orbiter and lander missions.						X	X	
1H2: Complete initial next decade planning mission architecture studies.							X	
1H32: Initiate the HEDS Technology/Commercialization program and establish a synergistic relationship with industry.							X	
1H3: Support an expanded, productive research community to include 975 investigations by 2001.						X		
1H4: Conduct outstanding peer-reviewed and commercial research on STS 107 to advance knowledge in the fields of medicine, fundamental biology, biotechnology, fluid physics, materials processing and combustion.						X		
1H5: Begin research on the International Space Station						X		
1H6: The Office of Space Flight will expedite a safety improvement program to ensure the continued safe operations of the Space Shuttle that ensures the availability of a safe and reliable Shuttle system to support Space Station			X					
1H7: Achieve 8 or fewer flight anomalies per mission.			X					
1H30: Achieve 100% on-orbit mission success			X					
1H10: Successfully complete the majority of the planned development schedules and milestones required to support the Multi-element Integration Testing		X						
1H11: Successfully complete the majority of the ISS planned on-orbit activities such as delivery of mass to orbit and enhanced functionality.		X						

HEDS FY01	Budget Category	Space Station	Space Shuttle	Paylaod and ELV Support	Space Operations	Life and Microgravity Sciences	HEDS Investments	Research and Program Management
Performance Target								
1H12: Successfully complete the majority of combined ISS planned operations schedules and milestones as represented by indicators of permanent human on-orbit operations.		X						
1H13: Successfully complete the majority of the planned research activities in support of initiation of on-orbit research opportunities.		X				X		
1H14: Successfully complete no less than 85% of the planned Russian Program Assurance schedules and milestones required for the development of the Propulsion Module.		X						
1H15: Successfully complete no less than 75% of the planned crew return capability schedules. FY01 indicators will include accomplishment of program schedule milestones for Phase 1 development of a crew return vehicle that could provide U.S. crew return capability.		X						
1H17: Develop new biomedical and technological capabilities to facilitate living and working in space and safe return to Earth.						X		
1H18: Develop and demonstrate technologies for improved life support systems.						X		
1H31: Initiate implementation of the Bioastronautics Initiative						X		
1H20: Increase the percentage of the space operations budget allocated to acquisition of communications and data services from the commercial sector to 15%.					X			

HEDS FY01	Budget Category	Space Station	Space Shuttle	Paylaod and ELV Support	Space Operations	Life and Microgravity Sciences	HEDS Investments	Research and Program Management
Performance Target								
1H21: Achieve at least 95 per cent of planned data delivery, on average, from space flight missions as documented in space, ground, deep space, and NASA integrated service networks performance metrics consistent with detailed program and project operations requirements in project service level agreements.					X			
1H22: Establish at least ten new, active industrial partnerships to research tomorrow's space products and improve industrial processes through NASA's Commercial Centers, and find opportunities for space experiments						X		
1H23 Foster commercial endeavors by reviewing and/or implementing new policies and plans, such as the Space Station resource pricing policy and intellectual property rights policy. Ensure that Space Station resources allocated to commercial research are utilized by commercial partners to develop commercial products and improve industrial processes.		X				X		
1H26: Support participation in HEDS research.						X		
1H29: Improve health of the NASA workforce						X		

Aero-Space Technology Enterprise

Mission

The Aero-Space Technology (AST) Enterprise mission is to pioneer the identification, development, verification, transfer, application, and commercialization of high-payoff aerospace technologies. Research and development programs conducted by the Enterprise contribute to national security, economic growth, and the competitiveness of American aerospace companies. The Enterprise plays a key role in maintaining a safe and efficient national aviation system and enabling an affordable, reliable space transportation system. The Enterprise directly supports national policy in both aeronautics and space as directed in the President's Goals for a National Partnership in Aeronautics and Research Technology, the National Space Policy, and the National Space Transportation Policy.

Implementation Strategy

The Enterprise manages a clearly defined portfolio of technology investments to ensure alignment with national policy, Agency goals, customer requirements, and budget availability. The investment strategies are focused on issues associated with future aviation and space systems. Enterprise objectives are outcome-focused and "stretch" beyond our current knowledge base. The outcome-focused nature of the objectives projects a preferred end-state within the air and space transportation systems. Designated Lead Centers have been assigned the responsibility to manage the implementation and execution phases of the technology programs. Enterprise programs are often conducted in cooperation with other Federal agencies, primarily the Federal Aviation Administration and the Department of Defense. These partnerships take advantage of the national investment in aeronautics and astronautics capabilities and eliminate unnecessary duplication.

The Enterprise supports the maturation of technology to a level such that it can be confidently integrated into current and new systems. In most cases, technologies developed by the Enterprise can be directly transferred to the external customer.

Enterprise Resource Requirements

The President has requested the following budget for FY 1999 to FY 2005 to support the accomplishment of AST goals:

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
NOA $M	1,339	1,125	1,193	1,549	1,949	2,245	2,303
CS FTE	4,227	4,227	4,414	4,463	4,576	4,564	4,537

Performance Measures

The following Targets have been established in support of the Enterprise's Strategic Goals and accompanying Objectives; the noted time horizons of 10, 15 and 25 years for these objectives correspond to 2007, 2012 and 2022, respectively:

Global Civil Aviation Goal — Develop an environmentally friendly global air transportation system for the next century of unquestioned safety that improves the Nation's mobility.

Objective - Reduce the aircraft accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years. (the reference baseline is Federal Aviation accident statistics for 1993 through 1996).

- Complete 75% of the conceptual designs of systems for preventing and mitigating accidents (programmatic performance indicators in appendix), and demonstrate tools for accident analysis and risk assessment; indicators include information data base and tool development, system architecture definition and evaluation, as well as ground and flight tests. (Target 1R1)

Objective - Reduce Emissions of future aircraft by a factor of three in 10 years and by a factor of five within 25 years. (the reference baseline is International Civil Aviation Organization 1996 emissions standards).

- Complete one system level technology benefit assessment, one component concept selection and one new material system; indicators include a technology benefit assessment, advanced concepts definition and selection, development of advanced materials and design methods. (Target 1R2)

Objective – Reduce perceived noise levels of future aircraft by a factor of two in 10 years, and by a factor of four in 25 years. (the reference baseline is representative 1997 production aircraft).

- Complete large-scale demonstration of a 2-5 decibel reduction in aircraft noise based on 1997 production technology, and initial assessments of concepts offering additional reduction; indicators are results of large scale component ground tests and analytical noise predictions, respectively. (Target 1R3)

Objective – While maintaining safety, triple the aviation system throughput in all weather conditions within 10 years (the reference baseline is 1997 operational data from the nation's top 64 airports).

- Complete the civil tiltrotor project by validating databases for contingency power, flight paths, and noise reduction, as well as complete at least one demonstration of an airspace management decision support tool; indicators include demonstrations of decision support and communication tools, as well as design databases. (Target 1R4)

Revolutionary Technology Leaps Goal – Revolutionize air travel and the way in which air and space vehicles are designed, built, and operated.

Objective – Invigorate the general aviation industry, so it can deliver 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 25 years.

- Complete the Advanced General Aviation Transport Experiments project by validating transportation system concepts through flight test and publish design guidelines; indicators include simulations and flight tests, and published design guidelines and standards. Also establish at least one partnership agreement on Small Aircraft Transportation System program. (Target 1R7)

Objective – Provide next generation design tools to increase design confidence, and cut the development cycle time for aircraft in half within 10 years (the reference baseline is representative 1997 industry timeframes).

- Develop at least three new design tools and accomplish at least four demonstrations of advances in computation and communications: indicators include computer testbed demonstrations, real-time remote access of data, and new design methods. (Target 1R8)

Objective – Provide next generation experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half within 10 years.

- Demonstrate two new concepts in flight and identify five new concepts for further examination; indicators include vehicle development, flight tests and systems analyses of advanced concepts. (Target 1R9)

Space Transportation Goal – Achieve the full potential of space for all human endeavor through affordable space transportation

Objective – Reduce the payload cost to low-Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years, and by an additional order of magnitude within 25 years.

- Complete assembly of the third X-34 test vehicle, demonstrate 75% of supporting technology developments (programmatic performance indicators in appendix), and complete competitive solicitations for expanded 2nd generation reusable launch vehicle efforts; indicators for supporting technology development include both flight tests and ground tests. (Target 1R10)

Objective – Reduce the cost of interorbital transfer by an order of magnitude and travel time for planetary missions by a factor of two within 15 years (the reference baseline is representative 1997 systems).

- Commence X-37 vehicle assembly, and complete one Pathfinder flight experiment. (Target 1R11)

Research and Development Services Goal – Enable, and as appropriate provide, on a national basis, world-class aerospace R&D services, including facilities and expertise

Objective – Provide world-class aerospace research and development services, facilities and expertise.

- Continue the solicitation of customer feedback on the services, facilities and expertise provided by the Aero-Space Technology Enterprise; indicators include two customer survey instruments utilized by the Aero-Space Technology Enterprise, along with documented cases of new technologies transferred to industry and other government agencies. (Target 1R12)
- Continue the implementation of current education outreach plans, and establish new plans for all new program activities initiated in FY 01; indicators include examples of educational outreach activities for current plans and the planning documentation for new programs. (Target 1R13)

Internal Assessment

The Aero-Space Technology Enterprise regularly reviews it's progress on achieving it's performance targets using NASA's established policies and procedures for program and project management. Evaluation is provided by the governing Program Management Council, either at the Agency-level or at the designated Lead Center, which meet at least quarterly to execute their oversight responsibilities. The AST Enterprise also relies on the extensive Safety, Quality, and Reliability processes and Center organizations to assure that performance in our facilities is maintained to standards appropriate for research and technology development operations.

External Assessment

The Aero-Space Technology Committee of the NASA Advisory Council will conduct annual assessments of the progress made by the OAT Enterprise in achieving its near-term technology objectives. This committee, and its nine technical subcommittees consisting of nearly 150 members from other government agencies, industry and academia that meet two to three times a year, will provide a qualitative progress measurement (Green, Yellow, or Red). "Green" will indicate that the objective was met; "Yellow" will indicate a concern that an objective was not fully accomplished; and "Red" will indicate that events occurred that prevented or severely impaired the accomplishment of the objective. The assessment will include commentary to clarify and supplement the qualitative measures.

Aero-Space Technology Enterprise FY 01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01#	FY 01 Targets	FY 01 Indicator Characterization
Global Civil Aviation	Reduce the aircraft accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years	1R1	NASA's research stresses aviation system monitoring and modeling, accident prevention and accident mitigation. The performance target is to complete 75% of the conceptual designs of systems for preventing and mitigating accidents (programmatic performance indicators in appendix), and to demonstrate tools for accident analysis and risk assessment.	FY 01 indicators include information data base and tool development, system architecture definition and evaluation, as well as ground and flight tests.
Global Civil Aviation	Reduce Emissions of future aircraft by a factor of two in 10 years, and by a factor of five in 25 years.	1R2	NASA's research stresses engine technology to reduce the emissions of oxides of nitrogen and carbon dioxide. The performance target is to complete one system-level technology benefit assessment, one component concept selection and one new material system.	FY 01 indicators include a technology benefit assessment, advanced concepts definition and selection, development of advanced materials and design methods.
Global Civil Aviation	Reduce perceived noise levels of future aircraft by a factor of two in 10 years, and by a factor of four in 25 years.	1R3	NASA's research has stressed reducing noise in the areas of engines, nacelles, engine/airframe integration, aircraft interiors and flight procedures. The performance target is complete large-scale demonstration of a 2-5-decibel reduction in aircraft noise based on 1997 production technology, and initial assessments of concepts offering an additional 3-decibel reduction.	FY 01 indicators are results of large-scale component ground tests.
Global Civil Aviation	While maintaining safety, triple the aviation system throughput in all weather conditions within 10 years	1R4	NASA's research stresses operations systems for safe, efficient air traffic management and new aircraft configurations for high productivity utilization of existing runways. The performance target is to complete the civil tiltrotor project by validating databases for contingency power, flight paths, and noise reduction, as well as complete at least one demonstration of an airspace management decision support tool.	FY 01 indicators include demonstrations of decision support and communication tools, as well as design databases.

Aero-Space Technology Enterprise FY 01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01#	FY 01 Targets	FY 01 Indicator Characterization
Revolutionary Technology Leaps	Invigorate the general aviation industry, so it can deliver 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 25 years.	1R7	NASA's research stresses operations systems for safe, efficient air traffic management and new aircraft configurations for high-productivity utilization of existing runways. The performance target is to complete the Advanced General Aviation Transport Experiments project by validating transportation system concepts through flight test and publish design guidelines, and to also establish at least one partnership agreement on Small Aircraft Transportation System program.	FY 01 indicators include simulations and flight tests, publishing of design guidelines and standards, signing of new partnership agreements.
Revolutionary Technology Leaps	Provide next-generation design tools to increase design confidence, and cut the development cycle time for aircraft in half in 10 years.	1R8	NASA's research stresses high-speed computing, high-capacity networks, and improved physics-based methods. The performance target is to develop at least three new design tools and accomplish at least four demonstrations of advances in computation and communications.	FY 01 indicators include computer testbed demonstrations, real-time remote access of data, and new design methods.
Revolutionary Technology Leaps	Provide next-generation experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half in 10 years	1R9	NASA's research stresses affordable flight demonstrations of revolutionary vehicle concepts (low-cost X-Planes) to accelerate technology advances in laboratory research, new design tools and advanced simulation. The performance target is to demonstrate two new concepts in flight and identify five new concepts for further examination.	FY 01 indicators include vehicle development, flight tests and systems analyses of advanced concepts.
Space Transportation	Reduce the payload cost to low-Earth orbit by an order of magnitude (from $10,000 to $1,000 per pound) within 10 years, and by an additional order of magnitude within 25 years.	1R10	NASA's research stresses highly reliable, fully reusable configurations, advanced materials and innovative structures. The performance target is to complete assembly of the third X-34 test vehicle, and demonstrate 75% of the technology developments (programmatic performance indicators in appendix) for reusable launch vehicles.	FY 01 indicators include vehicle development, flight tests and ground tests of advanced technologies.

Aero-Space Technology Enterprise FY 01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01#	FY 01 Targets	FY 01 Indicator Characterization
Space Transportation	Reduce the cost of interorbital transfer by an order of magnitude and travel time for planetary missions by a factor of two within 15 years.	1R11	NASA's research stresses technology for reusable, long-life, high-power electric and advanced, clean chemical engines for Earth orbital transfer and breakthrough propulsion, precision landing systems and aerocapture systems for planetary exploration. The performance target is to commence X-37 vehicle assembly, and complete one Pathfinder flight experiment.	FY 01 indicators include flight vehicle development progress and conduct of flight experiments.
Research & Development (R&D)	Provide world-class aerospace research and development services, facilities and expertise	1R12	Continue the solicitation of customer feedback on the services, facilities and expertise provided by the Aero-Space Technology Enterprise	FY 01 indicators include two customer survey instruments utilized by the Aero-Space Technology Enterprise, along with documented cases of new technologies transferred to industry and other government agencies.
Research & Development (R&D)	Provide world-class aerospace research and development services, facilities and expertise	1R13	Continue the implementation of current education outreach plans, and establish new plans for all new program activities initiated in FY 01.	FY 01 indicators include examples of educational outreach activities for current plans and the planning documentation for new programs.

AST FY01	AERO-SPACE FOCUSSED											AERO-SPACE BASE R&T								
	Budget Category	Aviation System Capacity	Aviation Safety Technology	High Performance Computing & Comm.	Ultra Efficient Engine Technology	Small Aircraft Transportation System	Quiet Aircraft Technology	X-33	X-34	Future-X	2nd Generation RLV	Operations Systems	Flight Research	Information Technology	Propulsion & Power	Rotorcraft	Vehicle Systems Technology	Space Transfer & Launch Technology	Commercial Technology	R&PM
Performance Target																				
Aviation Safety (1R1)			X									X		X	X	X	X			X
Environmental Compatibility - Emissions (1R2)					X								X		X					X
Environmental Compatibility - Noise (1R3)							X										X			X
Affordable Air Travel - Throughput (1R4)		X											X	X						X
General Aviation Revitalization (1R7)						X									X		X			X
Next-Generation Design Tools (1R8)				X										X		X	X			X
Next-Generation Experimental Aircraft (1R9)													X		X		X			X
Space Access (1R10)								X	X	X	X			X	X		X	X		X
In-Space Transportation (1R11)										X	X							X		X
R&D Services - Customer Feedback (1R12)																				X
R&D Services - Education Outreach (1R13)																				X

Manage Strategically

Goal

The goal of this process is to ensure that the Agency carries out its responsibilities effectively and safely and that management makes critical decisions regarding implementation activities and resource allocations that-support NASA's strategic, implementation, and performance plans.

For FY 2001 NASA's strategic management performance objectives (and associated performance targets) require the Agency to make the most effective use of appropriated funds, workforce, procurement processes, and information technologies.

Performance Measures

Goal: Ensure that the Agency meets its responsibilities safely and effectively, as it allocates its resources to support NASA's strategic, implementation, and performance Plans.

In order to know how successful we are in meeting the Manage Strategically goals and objectives, we have established four performance targets against which we will measure our progress.

Objective: Assess, document, communicate and mitigate the programmatic and technical risks associated with NASA programs and projects; focus special attention toward addressing and mitigating safety and health risks presented by our work environment and our projects.
As a part of assessing, documenting and mitigating the programmatic and technical risks associated with our programs ,our performance target will be to:

- Target: Increase the safety of NASA's infrastructure and workforce with facilities safety improvements, reduced environmental hazards, increased physical security, and enhanced safety awareness among its employees. 1MS1

One of the indicators used to evaluate our performance is whether we can reduce by 3% per year from the FY 97 baseline the overall occurrence of injuries (due to occupational injury or illness) to 1.15 occurrences per 100 workers. This indicator also measures compliance with the Administration's Federal Worker 2000 Presidential Initiative,
In order to evaluate the effectiveness and efficiency of Agency acquisitions our performance targets will be to:

Objective: Improve the effectivenes and efficiency of Agency acquisitions through the increased use of techniques and management that enhance contractor innovation and performance.

- Target: Continue to take advantage of opportunities for improved contract management by maintaining a high proportion of Performance Based Contracts (PBCs), and maintain significant contractor involvement in NASA programs for small businesses, minority institutions, and minority and women owned businesses. 1MS2

The percentage of awards to small and disadvantaged businesses and the obligation of at least 80% of the funds available for PBCs are two of the indicators that will be used to evaluate our performance against this target.

Objective: Optimize Agency investment strategies and systems to align human, physical, and financial resources with customer requirements, while ensuring compliance with applicable statutes and regulations.
The optimal use of Agency investments and systems to meet customer requirements will be evaluated against the performance target to:

- Target: Renew Agency's management systems, facilities, and human resources through updated use of automated systems, facilities revitalization, and personnel training. 1MS3

Among the indicators of progress, we will monitor the utilization of technology based learning, striving for a 10% increase over our usage in FY 2000.

Objective: Ensure that information technology provides and open and secure exchange of information, is consistent with Agency technical architectures and standards, demonstrates a projected return on investment, reduces risk, and directly contributes to mission success.
Our final performance target has been established to monitor our progress in ensuring that information technology provides an open and secure exchange of information while meeting technical and architectural standards and demonstrating a projected return on investments. Our performance target will be to:

- Target: Improve IT infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory", and enhance IT security through a reduction of system vulnerabilities across all NASA centers, emphasizing IT security awareness training for all NASA personnel. 1MS4

The indicators used to measure our service delivery include measurement of system capacity and the cost of units of capacity.

The Appendix contains a complete list of Manage Strategically indicators for FY 01.

MS FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01 #**	**FY01 Targets**	**FY01 Indicators**
Ensure that the Agency meets its responsibilities safely and effectively, as it allocates its resources to support NASA's strategic, implementation, and performance plans.	Assess, document, communicate, and mitigate the programmatic and technical risks associated with NASA programs and projects; focus special attention toward addressing and mitigating safety and health risks presented by our work environment and our projects.	1MS1	NASA will increase the safety of its infrastructure and workforce with facilities safety improvements, reduced environmental hazards, increased physical security, and enhanced safety awareness among its employees.	Examples of our indicators of progress toward our safety target include the award/modification of contracts for physical security upgrades to NASA's Minimum Essential Infrastructure (1MS1b), and achieving a lost-time employee injuries per 200,000 hours worked rate of 0.20 or less.
	Improve the effectiveness and efficiency of Agency acquisitions through the increased use of techniques and management that enhance contractor innovation and performance.	1MS2	Continue to take advantage of opportunities for improved contract management by maintaining a high proportion of Performance Based Contracts (PBC's), and maintain significant contractor involvement in NASA programs of small businesses, minority institutions, and minority and women owned businesses.	Examples of our indicators are maintaining PBC obligations to 80% of funds available for PBC's (excluding grants, cooperative agreements, actions under $100,000, SBIR, STTR, FFRDC's, intragovernmental agreements, and contracts with foreign governments or international organizations), and achieving at least an 8% goal for annual funding to small disadvantaged businesses.
	Optimize Agency investment strategies and systems to align human, physical, and financial resources with customer requirements, while ensuring compliance with applicable statutes and regulations.	1MS3	Renew Agency's management systems, facilities, and human resources through updated use of automated systems, facilities revitalization, and personnel training.	Examples of our indicators will be costing at least 75% of the resources authority available to cost during the fiscal year, increasing training opportunities in technology-based learning by 10%, and increasing by 20% employee use of technology-based learning opportunities

MS FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01 #**	**FY01 Targets**	**FY01 Indicators**
	Ensure that information technology provides an open and secure exchange of information, is consistent with Agency technical architectures and standards, demonstrates a projected return on investment, reduces risk, and directly contributes to mission success.	1MS4	Improve IT infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory," and enhance IT security through reduction of system vulnerabilities across all NASA centers, emphasizing IT security awareness training for all NASA personnel.	Indicators include measurement system capacity, cost of units of capacity, and customer satisfaction rating of service provided.

Manage Strategically FY01	Budget Category	Space Science	Earth Science	HEDS	Aero-Space Technology	Research & Program Management				
Performance Target										
NASA will increase the safety of its infrastructure and workforce with facilities safety improvements, reduced environmental hazards, increased physical security, and enhanced safety awareness among its employees. (1MS1)		X	X	X	X	X				
Continue to take advantage of opportunities for improved contract management by maintaining a high proportion of Performance Based Contracts (PBC's), and maintain significant contractor involvement in NASA programs of small businesses, minority institutions, and minority and women owned businesses. (1MS2)		X	X	X	X	X				
Renew Agency's management systems, facilities, and human resources through updated use of automated systems, facilities revitalization, and personnel training.		X	X	X	X	X				
Improve IT infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory" and holding costs per resource unit to the FY 98 baseline; and enhance IT Security through reduction of system vulnerabilities across all NASA Centers and through emphasis on IT security awareness training for all NASA personnel.		X	X	X	X	X				

Provide Aerospace Products and Capabilities

Goals

This process is the means by which NASA's Strategic Enterprises and their Centers deliver systems (ground, aeronautics, space), technologies, data, and operational services to NASA customers. Through the use of Agency facilities, customers can conduct research, explore and develop space, and improve life on Earth. This process is used to answer the Agency fundamental question: "What cutting-edge technologies, processes, techniques, and engineering capabilities must we develop to implement our research agenda in the most productive, economical, and timely manner?" The goal of the process is to enable NASA's Strategic Enterprises and their Centers to deliver products and services to customers more effectively and efficiently. The process is also used to enable the Communicate Knowledge process to extend the technology, research, and science benefits from NASA programs broadly to the public and commercial sectors.

Performance Measures

Goal: Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors

Objective - Meet schedule and cost commitments

NASA's role in the advancement of research and technology is conducted through the construction and operation of facilities such as telescopes, satellites, and ground-based laboratories and test facilities.

The performance target will be to:

- Keep the development and upgrade of major scientific facilities and capital assets within budget. On average, the Agency will not exceed 110 percent of cost and schedule estimates. Target 1P1

Objective - Improve and maintain NASA's engineering capability

The performance targets will be to:

- Ensure the availability of NASA's spacecraft and facilities by decreasing operating time lost to unscheduled downtime, relative to FY00 availability. Target 1P3

- Establish prototype collaborative engineering environments focused on the representative set of enterprise applications and evaluate performance against non-collaborative benchmarks. Target 1P2

Objective - Capture and Preserve Engineering and Technological Process Knowledge to Continuously Improve NASA's P/P Management

The performance target will be to

- Capture a set of best practices/lessons learned from each Program, to include at least one from each of the four PAPAC subprocesses documented in NPG 7120.5, commensurate with current program status. These data will be implemented in PAPAC process improvement and in Program/Project Management training. Target 1P4

Objective - Facilitate the insertion of technology into all programs and proactively transfer technology, form commercialization partnerships, and integrate all innovative approaches to strengthen U.S. competitiveness

The performance targets will be to:

- Dedicate the percent of the technology budget that was reported in the FY00 Performance Report toward leveraging with activities of other organizations. Target 1P6
- Dedicate 10 to 20 percent of the Agency's Research & Development budget to commercial partnerships. Target 1P5

PAPAC FY01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**01 #**	**FY01 Targets**	**FY01 Indicators**
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Reduce the cost and development time to deliver products and operational services	***1P1***	Meet schedule and cost commitments by keeping development and upgrade of major scientific facilities and capital assets within 110% of cost and schedule estimates, on average	Development schedule and cost data are drawn from NASA budget documentation for major programs and projects to calculate the average performance measures.
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Improve and maintain NASA's engineering capability	***1P2***	Establish prototype collaborative engineering environments focused on the representative set of enterprise applications and evaluate performance against non-collaborative benchmarks.	Evaluation of the readiness of the prototype and benchmarking of its performance will be completed.
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Improve and maintain NASA's engineering capability	***1P3***	Ensure the availability of NASA's spacecraft and ground facilities by decreasing the operating time lost to unscheduled downtime.	Each field center is reporting the operational downtime of the facilities identified for inclusion in the measure.
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Capture and preserve engineering and technological best practices and process knowledge to continuously improve NASA's program/project management	***1P4***	Capture a set of best practices/lessons learned from each Program, to include at least one from each of the four PAPAC subprocesses documented in NPG 7120.5, commensurate with current program status. Data will be implemented in PAPAC process improvement and in Program/Project Management training.	The effectiveness of the PAPAC processes are to be evaluated via the formal collection and utilization of inputs from projects and programs.
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Facilitate the insertion of technology into all programs and proactively transfer technology, form commercialization partnerships, and integrate all innovative approaches to strengthen U.S. competitiveness	***1P5***	Dedicate 10 to 20 percent of the Agency's Research & Development budget to commercial partnerships.	Each of the Enterprises are reporting the value of their contribution to commercial partnerships.
Enable NASA's Strategic Enterprises and their Centers to deliver products and services more effectively and efficiently while extending the technology, research, and science benefits broadly to the public and commercial sectors	Facilitate the insertion of technology into all programs and proactively transfer technology, form commercialization partnerships, and integrate all innovative approaches to strengthen U.S. competitiveness	***1P6***	Dedicate the percentage of the technology budget that was reported in the FY00 Performance Report toward leveraging with activities of other organizations.	Each of the Enterprises reports technology development activities leveraged through formal agreements.

PAPAC FY01	Budget Category	HEDS	Aero-Space Technology	Space Science	Earth Science
Performance Target					
Meet schedule and cost commitments by keeping development and upgrade of major scientific facilities and capital assets within 110% of cost and schedule estimates, on average. (1P1)		X	X	X	X
Establish prototype collaborative engineering environments focused on the representative set of enterprise applications and evaluate performance against non-collaborative benchmarks. (1P2)			X		
Ensure the availability of NASA's spacecraft and ground facilities by decreasing the operating time lost to unscheduled downtime. (1P3)		X	X	X	X
Capture a set of best practices/lessons learned from each Program, to include at least one from each of the four PAPAC subprocesses documented in NPG 7120.5, commensurate with current program status. Data will be implemented in PAPAC process improvement and in Program/Project Management training. (1P4)		X	X	X	X
Dedicate 10 to 20 percent of the Agency's Research & Development budget to commercial partnerships. (1P5)		X	X	X	X
Dedicate the percentage of the technology budget that was reported in in the FY00 Performance Report toward leveraging with activities of other organizations. (1P6)		X	X	X	X

Generate Knowledge

Goals

NASA provides new scientific and technological knowledge gained from exploring the Earth system, the solar system, and the universe beyond, and from conducting the necessary supporting research and development. The Generate Knowledge Process ensures that this information is shared with scientists, engineers, and technologists in industry, academia, and other organizations. In addition, natural resource managers, policy-makers, and educators benefit from this process. The goals of the Generate Knowledge Process are to extend the boundaries of knowledge of science, technology, and engineering, to capture new knowledge in useful and transferable media, and to share new knowledge with customers.

The Generate Knowledge Process is conducted by NASA's three scientific research enterprises: the Space Science Enterprise (SSE); the Earth Science Enterprise (ESE); and the Office of Life and Microgravity Sciences and Applications within the Human Exploration and Development of Space Enterprise (OLMSA/HEDS).

The Generate Knowledge Process does not include research of a proprietary industrial nature or research whose conduct or dissemination is limited for reasons of national security.

As provided in the *NASA Strategic Management Handbook*, the Generate Knowledge Process is composed of eight principal sub-processes (section 6.1.2). The Generate Knowledge Strategic Objectives mirror that set of subprocesses as follows:

1. Acquire Advice,
2. Plan and Set Priorities,
3. Select and Fund/Conduct R&A Programs,
4. Select and Implement Flight Missions,
5. Analyze Data (Initial),
6. Publish and Disseminate Results,
7. Create Data Archives, and
8. Conduct Further Research.

Performance Measures

Under the Strategic structure of a single goal and 5 objectives, NASA has defined 7 Target areas for GK for Fiscal Year 2001. Each Target has specific indicators that will provide a quantitative manner to show performance. The goal, objectives and targets are:

Goal: Extend the boundaries of knowledge of science and engineering, to capture new knowledge in useful and transferable media, and to share new knowledge with customers.

Objective: Acquire advice from diverse communities.

- Target: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will obtain scientific guidance from their investigator communities. 1G1

NASA relies on the guidance of outside customers and partners to maintain the vitality and efficacy of its research programs. This guidance is obtained through countless channels, both formal and informal. The principal vehicles for formal guidance are advisory committees chartered under the Federal Advisory Committee Act (FACA). At the conclusion of their meetings, which are conducted in conformance with the FACA statute, these committees develop and submit a letter report summarizing findings and recommendations. Each Strategic Enterprise has at least one advisory committee.

Objective: Plan and set research priorities

- Target: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will develop and/or release updated enterprise strategic plans. 1G2

The Strategic Enterprises operate strategic planning systems that define their goals and objectives and support agency-wide strategic management processes. Consistent with the requirements of the GPRA of 1993, the NASA strategic plan must be updated every 3 years. To support this planning cycle, each of the research offices independently updates its own Strategic Plan on a periodic basis.

Objective: Select, fund, and conduct research programs

- Target: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use competitive merit review wherever possible to select performers for science and basic technology research. 1G3

For selecting, funding, and conducting both research and analysis and core technology projects, the Space Science Enterprise, OLMSA, and the Earth Science Enterprise will use broad Agency announcement (AO, NRA, and Cooperative Agreement Notice solicitations) to competitively award 80 percent or more of the resources in these programs based on peer review.

Objective: Archive data and publish, patent, and share results

- Target: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will disseminate results of their research to a diverse population of users, including education users and the general public. 1G4

As a recipient of public funds for public purposes, NASA disseminates the results of its research in many forms to a client base whose interests range from highly technical to public information and educational. The primary means for the dissemination of OLMSA, Space Science Enterprise, and Earth Science Enterprise scientific findings are refereed journals, papers presented at professional meetings, and popular scientific periodicals. For all NASA research areas, collaborations with universities ensure that the insertion of the technical knowledge in academia and educational outreach to K-12 audiences is being expanded.

- Target: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will make science data obtained widely accessible as soon as possible after receipt and will maintain these data in open archives. 1G5

It is NASA policy to make scientific data returned by science missions widely accessible as soon as possible after receipt and to maintain these data thereafter in openly accessible archive databases. OLMSA, the Space Science Enterprise, and the Earth Science Enterprise support a number of discipline-based archiving facilities and programs.

Objective: Collaborate with old new partner.

- Target: Work with other federal agencies and U.S. industry to complement and support our activities. 1G6

NASA strives to maximize the research outcomes by leveraging resources with other National agencies and the private industry. This target will establish and implement Memoranda of Understanding (MOUs) and Memoranda of Agreement (MOAs) with U.S. Federal agencies and industry for appropriate partnerships in research areas of shared interest.

- Target: Pursue mutually beneficial cooperative activities in aeronautics and space with other nations. 1G7

NASA strives to leverage resources with other space agencies with the goal of minimizing the duplication of efforts worldwide. This target will establish and implement Letters of Agreement (LOAs) and Memoranda of Understanding (MOUs) for appropriate partnerships with foreign space agencies for cooperative activities.

Generate Knowledge FY01 Performance Plan

Strategic Plan Goal	Strategic Plan Objective	01 #	FY01 Targets	FY01 Indicators
Extend the boundaries of knowledge of science and engineering, to capture new knowledge in useful and transferable media, and to share new knowledge with customers	**Acquire advice from diverse communities**	**1G1**	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will obtain scientific guidance from their investigator communities.	At least seven letters of advice will be received from the enterprises' FACA-chartered advisory committees.
	Plan and set research priorities	**1G2**	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will develop and/or release updated enterprise strategic plans.	The Space Science Enterprise and the Earth Science Enterprise will release new enterprise strategic plans, and OLMSA/HEDS will review its new strategic plan with their advisory bodies.
	Select, fund, and conduct research programs	**1G3**	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use competitive merit review wherever possible to select performers for science and basic technology research.	Taken together, the Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use AOs, NRAs, and Cooperative Agreement Notice solicitations to award 80 percent or more of science and basic research funds via merit competition.
	Archive data and publish, patent, and share results	**1G4**	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will disseminate results of their research to a diverse population of users, including education users and the general public.	Research programs of the Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS, taken together, will account for 5 percent of the 150 "most important stories" in the annual review by *Science News*. The three enterprises will achieve their individual indicators in education and public outreach and publication of research progress. The three enterprises will maintain and periodically update publicly accessible web sites for active missions.
		1G5	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will make science data obtained widely accessible as soon as possible after receipt and will maintain these data in open archives.	The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will achieve their specific individual indicators for ensuring mission data maintenance and access.
	Collaborate with old and new partners	**1G6**	Work with other federal agencies and U.S. industry to complement and support our activities.	Establish and implement MOUs and MOAs with U.S. Federal agencies and industry for appropriate partnerships in research areas of shared interest.
		1G7	Pursue mutually beneficial cooperative activities in aeronautics and space with other nations.	Establish and implement LOAs and MOUs for appropriate partnerships with foreign space agencies for cooperative activities.

Generate Knowledge FY01	Budget Category	Space Science	Earth Science	HEDS	Aero-Space Technology
Performance Target					
The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will obtain scientific guidance from their investigator communities. (1G1)		X	X	X	
The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will develop and/or release updated enterprise strategic plans.(1G2)		X	X	X	
The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use competitive merit review wherever possible to select performers for science and basic technology research. (1G3)		X	X	X	
The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will disseminate results of their research to a diverse population of users, including education users and the general public.(1G4)		X	X	X	
The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will make science data obtained widely accessible as soon as possible after receipt and will maintain these data in open archives. (1G5)		X	X	X	
Work with other federal agencies and U.S. industry to complement and support our activities. (1G6)		X	X	X	
Pursue mutually beneficial cooperative activities in aeronautics and space with other nations.(1G7)		X	X	X	

Communicate Knowledge

Goals

The Communicate Knowledge (CK) process facilitates the distribution of information on NASA's missions and discoveries. It insures increased public understanding of science and technology, promotes the application of NASA-generated information, and inspires achievement and innovation. The process insures that knowledge derived from NASA research programs is available to meet the specific needs and interests of constituent groups. It begins at the inception of a research project and increases in intensity as the effort reaches maturity to insure the appropriate delivery, archiving, and future convenient access of all research results. The goal of the Communicate Knowledge Process is to insure that information derived from NASA's research efforts is distributed in a useful, timely, and reliable manner.

The Objectives described in the NASA Strategic Plan for this cross-cutting process are:

- **Highlight existing and identify new opportunities for NASA's customers, including the public, the academic community, and the Nation's students, to participate directly in space research and discovery experience**

- **Improve the external constituent communities' knowledge, understanding, and use of the results and opportunities associated with NASA's programs**

Performance Measures

The Agency has defined 4 Target areas for CK for Fiscal Year 2001. Each Target has specific indicators that will provide a quantitative manner to show performance. The targets are listed below:

- Convey information about, and knowledge generated by NASA's programs, to the public Target 1CK1

By maintaining an exhibits loan service, a fine-arts program, and by providing live satellite interviews with astronauts, program managers, and other Agency officials, NASA hopes to expose more people to the activities of the Nation's Aeronautics and Space programs. Through increased availability of documentation and digital images, the agency will provide scientists and the public greater access to NASA generated knowledge.

- Assist the public and customers to locate and retrieve information on, or that has been generated by, a NASA program. Target 1CK2

Improve NASA's service to the public who use the Scientific Technical Information and the NASA Image Exchange Help Desks and increased utility of the NASA world wide web pages in terms of capacity and ease of locating areas of interest – based on the public's demand.

- Facilitate the transfer of NASA generated technology and innovations to private industry. Target 1CK3

Increase the opportunities for transferring technology from NASA to private industry and the public, through the Internet using the TechTracS database and by producing a series of technology publications.

- Support educational excellence and reach out to the underserved and underrepresented minority community. Target 1CK4 Through the exposure of students in grades kindergarten through high school, NASA expects to generate more interest in space, aeronautics, and science for the next generation of the American workforce. We will accomplish this through direct interface with students, their teachers and the school faculty; increasing the number of sites that offer science and engineering curriculum to the underrepresented and minority students; and increasing the involvement of minority universities through sponsored research projects.

The Agency is in the process of reviewing and modifying this cross-cutting process. Any changes will be reflected in the FY02 or FY01 revised final plan.

Communicate Knowledge FY 01 Performance Plan				
Strategic Plan Goal	**Strategic Plan Objective**	**FY01#**	**Targets**	**FY 01 Indicators**
Ensure that NASA's customers receive the information derived from the Agency's research and development efforts that they want, when they want it, for as long as they want it.	• Highlight existing and identify new opportunities for NASA's customers, including the public, the academic community, and the Nation's students, to participate directly in space research and discovery experience	1CK1	Convey information about, and knowledge generated by NASA's programs, to the public	By maintaining an exhibits loan service, a fine-arts program, and by providing live satellite interviews with astronauts, program managers, and other Agency officials NASA hopes to expose more people to the activities of the Nation's Aeronautics and Space programs. Through increased availability of documentation and digital images, the agency will provide scientists and the public greater access to NASA generated knowledge.
		1CK2	Assist the public and customers to locate and retrieve information on, or that has been generated by, a NASA program	Improve NASA's service to the public who use the Scientific Technical Information and the NASA Image Exchange Help Desks and increased utility of the NASA world wide web pages in terms of capacity and ease of locating areas of interest – based on the public's demand.
	• Improve the external constituent communities' knowledge, understanding, and use of the results and opportunities associated with NASA's programs	1CK3	Facilitate the transfer of NASA generated technology and innovations to private industry	Increase the opportunities for transferring technology from NASA to private industry and the public, through the internet using the TechTracs database and by producing a series of technology publications.
		1CK4	Support educational excellence and reach out to the underserved and underrepresented minority community	Through the exposure of students in grades kindergarten through high school, NASA expects to generate more interest in space, aeronautics, and science for the next generation of the American workforce. We will accomplish this through direct interface with students, their teachers and the school faculty; increasing the number of sites that offer science and engineering curriculum to the underrepresented and minority students; and increasing the involvement of minority universities through sponsored research projects.

Communicate Knowledge - FY01	Budget Category	HEDS	Aero-Space Technology	Space Science	Earth Science	Academic Programs	Research & Program Management
Performance Target							
Convey information about, and knowledge generated by NASA's programs, to the public (1CK1)							X
Assist the public and customers to locate and retrieve information on, or that has been generated by, a NASA Program (1CK2)							X
Facilitate the transfer of NASA generated technology and innovations to private industry (1CK3)			X				
Support educational excellence and reach out to the underserved and underrepresented minority community (1CK4)		X	X	X	X	X	

APPENDIX

FY 2001 PERFORMANCE PLAN

Space Science Enterprise Performance Targets and Indicators

Target 1S1: Successfully develop and launch no less than three of four planned missions within 10% of budget and schedule.

Performance indicators have been identified for four missions scheduled to launch in FY01. Indicators have also been established for other missions in development.

- GALEX Development: Deliver the Galaxy Evolution Explorer (GALEX) for launch; successful launch and check-out.
- MAP Development: Deliver the Microwave Anisotropy Probe (MAP) for launch; successful launch and check-out.
- GP-B Development: Deliver GP-B for launch; successful launch and check-out.
- CATSAT Development: Deliver the Cooperative Astrophysics and Technology Satellite (CATSAT) for launch; successful launch and check-out.
- SIRTF Development: Spacecraft complete and ready for integration with Cryogenic Telescope Assembly (CTA). CTA complete and delivered to spacecraft contractor for integration with spacecraft.
- SOFIA Development: Install Protoflight 747 Cavity Door on Section 46 Cavity Mockup.
- HST Development: Install two key HST upgrades on Servicing Mission 3B: Advanced Camera for Surveys (ACS) and Solar Array 3 (SA3).
- Payload & Instrument Development - Planck: The Preliminary Breadboard Cooler Performance Report will be delivered.
- Explorer Program Future Missions: MIDEX 3&4: Throughout FY 2001, continue full-scale development of the Swift Gamma Ray Burst Explorer (Swift) and the Full-sky Astrometric Mapping Explorer (FAME). SMEX 8&9: Down-selection planned.

Target 1S2: Obtain expected scientific data from 80% of operating missions.

Performance indicators have been identified for six operating missions. An indicator has also been established for another mission scheduled to launch in FY01; this indicator is to be utilized upon successful launch.

- HST Operations: Maintain an average on-target pointing efficiency of 35%, excluding the servicing mission and checkout and verification period.
- CXO Operations: Instruments meeting nominal performance expectations; complete 80% of pre-planned and commanded observations with 95% of science data recovered on ground.
- RXTE Operations: Successful operation of the Proportional Counter Array , the High Energy X-ray Timing Experiment, and the All-Sky Monitor instruments, with an average of 3 PCUs (proportional counter units) operating at 45% efficiency or higher; 90% of data recovered; ASM data posted on the web within 7 days.
- ACE Operations: Measure the composition and energy spectra of heavy nuclei in six solar energetic particle events; measure the frequency and composition of coronal mass ejection events during the year; maintain real-time solar wind data 90% of the time.

- FUSE Operations: Measure interstellar gas velocities as small as 15 km per second, make 200 independent observations on line of sight in the Milky Way and nearby Galaxies; deliver 95% of the calibrated science observations to the FUSE archive on time.
- SWAS Operations: Dedicate 6000 hours (on-source plus reference positions) to observations of galactic star forming regions, asymptotic giant branch stars, planetary nebulae, supernovae remnants, planets, and comets.
- MAP Operations: Conduct early operations, including achieving the required trajectory to L2; interrupt sky-scanning observing mode no more than 4 times per year; successfully dump data daily to DSN with transfer to GSFC.

Target 1S3: Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in astronomy rocket and balloon flights, and by making satisfactory research progress in related Research and Analysis (R&A) and Data Analysis (DA) programs.

Performance indicators have been drawn from technology development objectives for three missions. Indicators have also been established for achievement of mission success for astronomy rocket and balloon flights and research progress in the R&A and DA programs.

- NGST Technology Development: Inflatable Shield in Space (ISIS) technology demonstration ready to fly on Shuttle; release AO for Science Instrument; down-select to a single phase 2 prime contractor.
- FIRST Technology Development: Complete the qualification mirror (QM) fabrication.
- GLAST Technology Development: Conduct successful NAR for instrument development, project definition, and interface development.
- Sounding Rocket Flights: Achieve launch success rate of 80% for sounding rocket flights.
- Balloon Flights: Achieve launch success rate of 80% for balloon flights.
- Research and Analysis: Issue NASA Research Announcement (NRA) for Research Opportunities in Space Science (ROSS).

Target 1S4: Successfully develop and launch no less than one of two missions within 10% of budget and schedule.

Performance indicators have been identified for two missions scheduled to launch in FY01. Indicators have also been established for other projects in development.

- Mars '01 Orbiter Development: Deliver for launch; successful launch and check-out.
- Genesis Development: Deliver for launch; successful launch and check-out.
- Rosetta Development: Deliver the flight units for the four U.S.-provided instruments or instrument subsystems to ESA.
- TWINS Development: Continue instrument development and deliver Flight Unit #1 for Integration and Test.
- CONTOUR Development: Successful CDR, meeting all program level requirements.
- Discovery Program Future Missions: New mission selection.

Target 1S5: Obtain expected scientific data from 80% of operating missions.

Performance indicators have been identified for nine operating missions. Indicators have also been established for other missions scheduled to launch in FY01; these indicators are to be utilized upon successful launch.

- ISTP Operations: Continue to collect 85% of data acquired from the ISTP spacecraft and successfully execute the Wind trajectory plan.
- Cassini Operations: Complete development, test, and load Attitude and Articulation Control Subsystem flight software version A8.0; complete development, test, and load Command and Data Subsystem software version V9.0.
- Voyager Operations: Upload overlay command messages to Voyager 1 quarterly; record plasma wave data weekly (Voyager 1 and 2); return science data 10 hours per day .
- Ulysses Operations: Capture at least 90% of available Ulysses science data. These will be the only data observed from outside-of-the-ecliptic plane.
- SAMPEX Operations: Obtain at least 60% data coverage from at least three of SAMPEX's four instruments.
- FAST Operations: Simultaneously gather particle and fields data during 75% of its high altitude encounters with the northern hemisphere auroral zone and 25% of its high altitude encounters with the southern hemisphere auroral zone; successfully deliver at least 85% of these data.
- TRACE Operations: Conduct solar observing operations during all orbits where EUV images of the sun can be obtained using a 5-day-per-week/8-hour-per-day planning and operations cycle; deposit all TRACE data products into a web-based data system.
- Stardust Operations: Earth flyby for gravity assist.
- Mars Global Surveyor (MGS) Operations: Complete primary mapping mission.
- TIMED Operations: One complete season (at least 90 days) of successful data collection at the required resolution and accuracy.
- HESSI Operations: Obtain hard-X-ray images of solar flares with angular resolution approximately 2 arcseconds and energy resolution approximately 1 keV (kilo-electron volts); obtain high-resolution X-ray and gamma-ray spectra of solar flares with approximately 1 keV energy resolution to energies as high as 20 MeV (million electron volts).
- IMAGE Operations: Acquire measurements at minute time scales, returning 85% real-time coverage of the Earth's magnetospheric changes; perform routine pipeline processing of browse products and deliver to the National Space Science Data Center (NSSDC) within 72 hours.
- Genesis Operations: If launched, start operations, insert spacecraft into L-1 halo orbit and start science phase.
- Mars '01 Orbiter Operations: Successfully perform required trajectory correction maneuvers and planned instrument checkout activities.

Target 1S6: Perform innovative scientific research and technology development by meeting technology development objectives for major projects, by achieving mission success in space physics rocket and balloon flights, and by making satisfactory research progress in related R&A and DA programs.

Performance indicators have been drawn from technology development objectives for three missions, as well as for future mission sets and for specific multi-mission technology development efforts. Indicators have also been established for achievement of mission success for space physics rocket and balloon flights and research progress in the R&A and DA programs.

- Solar-B Technology Development: Deliver engineering model of the optical telescope and x-ray telescope.
- STEREO Technology Development: Successfully complete Phase B effort including Confirmation Review.
- Solar Probe Technology Development: Begin Solar Probe prototype thermal shield fabrication.
- Future ST Probes Technology Development: Complete preliminary concept definitions for spacecraft systems and instruments for Magnetospheric Multiscale.
- Future Deep Space Technology Development: Deliver X-2003 Level 1-3 Requirements Documents; define subsystem interfaces; demonstrate intermediate-level multi-functional structures (MFS); complete definition of system architecture; evaluate key risk areas and pass decision gates.
- CISM Technology Development: Demonstrate and deliver prototype advanced power transistor [0.35 micron SOI (Silicon On Insulator) CMOS (Complementary Metallic Oxide Semiconductor)]; demonstrate Active Pixel Sensor with advanced processing capabilities on a single chip.
- X-2000 Technology Development: Deliver engineering model and flight set of avionics.
- Sounding Rocket Flights: Achieve launch success rate of 80% for sounding rocket flights.
- Balloon Flights: Achieve launch success rate of 80% for balloon flights.

Target 1S7: Perform innovative scientific research and technology development by meeting interferometry technology development objectives and by making satisfactory research progress in related R&A programs.

Performance indicators have been drawn from technology development objectives for three missions. Indicators have also been established for the Keck Interferometer project and for achievement of research progress in the R&A program.

- SIM Technology Development: Complete System Requirements Review (SRR), initiate Phase B, and demonstrate stabilization for nulling to one nanometer.
- TPF Technology Development: Award architectural definition contracts, develop Request For Proposals (RFP) for second phase of industrial contracts, and test starlight nulling breadboard.
- ST-3 Technology Development: Successfully complete Preliminary Design Review (PDR); successfully complete project and spacecraft Critical Design Review (CDR).
- Keck Interferometer Technology Development: Combine 2 Keck telescopes; install first outrigger telescope.
- Research and Analysis: Issue NASA Research Announcement (NRA) for Research Opportunities in Space Science (ROSS).

Target 1S8: Perform innovative scientific research and technology development by meeting technology development objectives and by making satisfactory research progress in the related R&A program, including the Astrobiology program.

Performance indicators have been drawn from the technology development objectives for the Europa Orbiter. Indicators have also been established for achievement of research progress in the R&A program, including especially the Astrobiology program.

- Europa Orbiter Technology Development: Complete Preliminary Design Review (PDR).
- Astrobiology Research: High-priority studies identified in the Astrobiology Roadmap will be carried out, the National Astrobiology Institute will conduct institute-wide functions using internet/video conferencing capabilities (i.e., executive council meetings, science seminars, group collaborations, education/outreach), and Institute research publications will reflect its interdisciplinary nature.
- Research and Analysis: Issue NASA Research Announcement (NRA) for Research Opportunities in Space Science (ROSS).

Target 1S9: Continue and expand the integration of education and enhanced public understanding of science with Enterprise research and flight mission programs.

Performance indicators have been identified for education and public outreach efforts.

Education and Public Outreach: Successful achievement of at least six of the following eight objectives will be made.

- Every mission initiated in FY 2001 will have a funded education and outreach program with a comprehensive education and outreach plan prepared by its PDR.
- By the end of FY01, 10 percent of all research grants will have a funded education and outreach program underway.
- Enterprise-funded education and outreach activities will be in planning or implementation in at least 34 states.
- At least five Enterprise-funded research, mission development or operations, or education projects will be underway in Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges, with at least one being underway in an institution of each type.
- The Enterprise will provide exhibits, materials, workshops, and personnel at a minimum of five national and three regional education and outreach conferences.
- At least five major Enterprise-sponsored exhibits or planetarium shows will be on display or on tour at major science museums or planetariums across the country.
- The first comprehensive Space Science Enterprise Education/Outreach Report will be prepared that describes participants, audiences, and products for Enterprise education and outreach programs.
- Initial results of a pilot assessment of the Enterprise's approach to education and outreach will be available for determining whether adjustments in program direction or organization are needed.

Target 1S10: Investigate the composition, evolution, and resources of Mars, the Moon, and small bodies by successfully launching a Mars mission, by obtaining data from operational spacecraft, and by making satisfactory progress in related R&A and DA programs.

Performance indicators have been identified for the Mars '01 Orbiter, scheduled to launch in FY01, and for a Discovery mission scheduled to be in development. Other indicators have also been identified for an operating mission, as well as for achievement of research progress in related R&A and DA programs.

- Mars '01 Orbiter: Deliver for launch, within 10% of planned development budget and schedule; successful launch and check-out.
- CONTOUR Development: Successful CDR, to document that the design meets all program level requirements.
- Mars Global Surveyor Operations: Complete primary mapping mission.
- Research and Analysis: Issue NASA Research Announcement (NRA) for Research Opportunities in Space Science (ROSS).

Target 1S11: Develop the knowledge to improve the reliability of space weather forecasting by obtaining scientific data from three of five missions and by making satisfactory progress in related areas in R&A and DA programs.

Performance indicators have been identified for four operating missions. Indicators have also been established for another mission scheduled to launch in FY01 (to be utilized upon successful launch), as well as for achievement of research progress in the R&A and DA programs.

- ISTP Operations: Continue to collect 85% of data acquired from the ISTP spacecraft and successfully execute the Wind trajectory plan.
- ACE Operations: Measure the composition and energy spectra of heavy nuclei in six solar energetic particle events; measure the frequency and composition of coronal mass ejection events during the year; maintain real-time solar wind data 90% of the time.
- SAMPEX Operations: Obtain at least 60% data coverage from at least three of SAMPEX's four instruments.
- TRACE Operations: Conduct solar observing operations during all orbits where EUV images of the sun can be obtained using a 5-day-per-week/8-hour-per-day planning and operations cycle; deposit all TRACE data products into a web-based data system.
- HESSI Operations: Obtain hard-X-ray images of solar flares with angular resolution approximately 2 arcseconds and energy resolution approximately 1 keV (kilo-electron volts); obtain high-resolution X-ray and gamma-ray spectra of solar flares with approximately 1 keV energy resolution to energies as high as 20 MeV (million electron volts).
- Research and Analysis: Issue NASA Research Announcement (NRA) for Research Opportunities in Space Science (ROSS).

Target 1S12: Plan, develop, and validate new technologies needed to enable future research and flight missions by achieving performance objectives in core technology programs and by making progress as planned in the Flight Validation program.

Performance indicators have been identified for core technology programs (information systems, intelligent systems, high performance computing, and Explorer program technology), as well as for the Flight Validation program.

- Information Systems: Demonstrate Virtual Observatory capability from investigator workstation for multi-wavelength discovery, analysis, and visualization across collective set of space and ground astronomical surveys; demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of future Mars missions.
- Intelligent Systems: Awards will be made at the beginning of the 2001 program year. A second research opportunity cycle will begin in late 2001, targeted toward a second set of awards in mid-2002.
- High Performance Computing: Demonstrate a real-time capability with software-implemented fault tolerance for embedded scalable computers. Real-time performance latencies of less than 20 milliseconds are to be sustained at fault rates characteristic of deep space and low-Earth orbit (LEO).
- Explorer Program Technology: Complete 45 Explorers Technology Investigations selected in FY99. Implement awards for additional investigations planned for selection in FY00.
- Flight Validation: Complete ST-5 CDR.

New Initiative

Living With a Star: Further understanding of basic natural processes and the effects of solar variability on humans and technology.

Performance indicators have been established for Living With a Star.

- Strategic Plan: Complete Living With a Star Strategic Plan, including mission architecture, for the OSS Strategic Plan.
- Solar Dynamics Observatory: Complete definition study for the Observatory, the first major new flight mission for Living With a Star.
- Research & Data Analysis: Initiate targeted data analysis and modeling research grants program.

Earth Science Enterprise Performance Targets and Indicators

Target 1Y1: Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives.

- The Earth Science Enterprise (ESE) will successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Science research and applications goals and objectives.
- At least 90% of the total on-orbit instrument complement will be operational.

Target 1Y2: Successfully disseminate Earth Science data to enable our science research and applications goals and objectives.

- Make available data on prediction, land surface, and climate to users within 5 days.
- Increase by 20% the volume of data archived compared to FY00 (target =442 terabytes).
- Increase the number of distinct Earth Observing System Data and Information System (EOSDIS) customers by 20% compared to FY00 (target = 1.5 million).
- Increase products delivered from the Distributed Active Archive Centers (DAACs) by 10% compared to FY00 (Target = 5.4 million).
- User satisfaction: Increase the number of favorable comments from DAAC and Earth Science Information Partner (ESIP) users as recorded in the customer contact logs over FY00. Implement user satisfaction survey.
- Decrease total percentage of order errors by 5% over FY00.

Target 1Y3: Explore the dynamics of the global carbon cycle by developing, analyzing, and documenting multi-year data sets.

- Develop a multiyear global time series of phytoplankton biomass and primary productivity for assessing interannual variability in marine ecosystems on regional scales and daily to interannual time scales. Collect near-daily global measurements of ocean chlorophyll and primary productivity using Moderate Resolution Imaging Spectroradiometer (MODIS) on the EOS Terra and Aqua satellites, merged with SeaWifs data.
- Continue to refresh the global archive of 30 m land imagery seasonally with Landsat-7.
- Use of MODIS on Terra and Aqua to estimate the efficiency of the carbon uptake by phytoplankton (i.e., photosynthesis) for the first time. Also, demonstrate the value of such measurements in assessing carbon and nitrogen cycling in the open ocean by testing their utility in biogeochemical models.
- Estimate global carbon stocks and the role of land ecosystems, and evaluate human impacts on land cover changes. Develop the first global sample of vegetation height and vertical structure by using data from first Earth System Science Pathfinder (ESSP) mission, the Vegetation Canopy Lidar (VCL). Canopy height will be estimated to within 1 meter.

Target 1Y4: Explain the dynamics of global carbon cycle by building improved models and prediction capabilities.

- Through incorporation of data from field experiments and satellite data analysis funded by the Biology and Biogeochemistry of EcoSystems and the Global Carbon Cycle research and analysis programs; improve, by at least 15%, the ecological models needed to predict ecosystem responses to global environmental changes. This work will be done by NASA-funded investigators at universities and government laboratories.
- Provide information to understand remotely sensed observations of productivity that will be useful for improved prediction and management of food and fiber production. This will be accomplished by extending the long-term 1-4 km satellite record of global terrestrial productivity and its seasonal and interannual dynamics that was begun with the Advanced Very High-Resolution Radiometer (AVHRR). Continued data set with the near-daily global measurements from instruments on the EOS Terra spacecraft, using primarily the MODIS instrument.

Target 1Y5: Explore the dynamics of global water cycle by developing, analyzing, and documenting multi-year data sets.

- Resolve the wide disparity of precipitation estimates that currently exist to within 20 percent, thus improving our understanding of the global water cycle. The Tropical Rainfall Measuring Mission (TRMM) will obtain accurate maps of the diurnal cycle of precipitation and, in conjunction with a 10+ year reanalysis of SSM/I data, set a benchmark allowing us to define the natural variability and climatology for tropical precipitation.
- Decrease the uncertainty in determinations of radiation forcing and feedback, and thereby increase accuracy in our knowledge of heating and cooling of the Earth's surface and its atmosphere. Continue the analysis of global measurements of the radiative properties of clouds and aerosol particles being made by the MODIS, the Multi-Angle Imaging Spectrometer (MISR), and the Clouds and Earth's Radiant Energy System (CERES) instruments on the EOS Terra satellite.

Target 1Y6: Explain the dynamics of global water cycle by building improved models and prediction capabilities.

- Improve current understanding and model the large-scale effects of clouds in climate. Complete collection and processing of satellite data needed for the multi-decadal global cloud climatology being developed under the International Satellite Cloud Climatology Project (ISCCP).
- Validate parameterizations of Earth's radiative processes in models that simulate the cycling of fresh water through Earth's atmosphere. Complete a decadal Surface Radiation Budget (SRB) climatology.
- Demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture from airborne platforms, in preparation for a space-flight trial of soil moisture remote sensing. Soil moisture is an important land surface state variable, currently unmeasured at large spatial scales, that affects weather and climate.

Target 1Y7: Explore the dynamics of long term climate variability by developing, analyzing, and documenting multi-year data sets.

- Complete detailed mapping of thinning/thickening rates for all major ice catchments on the Greenland Ice Sheet. This will serve as a baseline for future satellite-based surveys, to determine the behavior of the ice sheet and its influence on global sea level change. Use airborne laser altimeter data and analysis from the Climate Variability and Prediction Program.
- Use Jason-1 satellite data to continue the measurement of ocean basin-scale sea-level variability and reducing errors to less than 3cm.
- Provide a quantitative understanding of the solar forcing of Earth's climate. Continue acquisition of a total solar irradiance dataset for the complete period of maximum solar activity. Continue the high precision, multi-decadal record of total solar irradiance measurements towards capturing three solar cycles. Enabled by the launch of Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT) in FY00.

Target 1Y8: Explain the dynamics of long term climate variability by building improved models and prediction capabilities.

- Develop and the capability to measure and diagnose open ocean variations in salinity by 0.1 psu in preparation for a space-based system.

- Improve the understanding and modeling of the aerosol radiative forcing of climate and its anthropogenic component. Develop and validate aerosol retrieval and cloud screening algorithms, and processing of satellite data and transport model evaluations for the 20-year climatology of aerosol optical thickness and particle size.

- Demonstrate the experimental seasonal climate predictions based on observations from operating satellites. Use next-generation computing systems and new coupled air-ocean-land-ice models, incorporating all available satellite observations (e.g., TOPEX, Jason, Seawinds, TRMM, SeaWIFS, and MODIS) of key ocean surface parameters such as wind vectors and altimetry.

- Enhance the accuracy of long-term climate variability and change models.

Target 1Y9: Explore the dynamics of atmospheric composition by developing, analyzing, and documenting multi-year data sets.

- Provide continuity of multi-decadal total ozone concentration measurements to aid in characterization of long-term evolution of ozone and enable assessment of ozone recovery processes.
- Continue to monitor atmospheric concentrations of chlorofluorocarbons (CFCs) and new industrial substitutes to understand their impact on ozone concentration.

- Develop a comprehensive climatology of high-resolution ozone vertical distribution in the southern subtropics. This climatology will be used to verify the quality of experimental algorithms used to obtain tropospheric ozone from Total Ozone Mapping Spectrometer (TOMS) data.
- Characterize long-term evolution and interannual variability in high latitude ozone, aerosol, and polar stratospheric cloud profiles.
- Obtain the first measurement of sunrise-to-sunset variations in global ozone aerosol distributions. Also, obtain the first daily diurnally integrated estimates of surface UV radiation using satellite data for the entire sunlit Earth.

Target 1Y10: Explain the dynamics of atmospheric chemistry by building improved models and prediction capabilities.

- Provide increased prognostic ability for Northern Hemisphere high latitude ozone loss in an atmosphere perturbed by an increased abundance of greenhouse gases. This will be accomplished via a comprehensive analysis of data from the SOLVE campaign.
- Provide improved assessment of role of the global budget of carbon monoxide and methane (including its role in the global carbon cycle) through the development of the first global climatology of carbon monoxide and total column methane. This will be accomplished via use of Measurements of Pollution in the Troposphere (MOPITT) instrument aboard the EOS-Terra satellite.
- Characterize atmospheric plume flowing out of East Asia, its evolution as it transits eastward over the Pacific Ocean, and its contribution to global atmospheric chemical composition. Conduct the Transport and Chemical Evolution over the Pacific (TRACE-P) airborne campaign using DC-8 and P3-B together with satellite data and chemistry/transport models.

Target 1Y11: Explore the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets.

- Enable near-real-time assessment of ground deformation for disaster response after earthquakes, continuous monitoring of large structures over time to detect subsidence or landslide vulnerability, and swelling of the ground as a precursor to explosive volcanic eruptions. Provide daily orbit solutions for Global Positioning System (GPS) constellation as a basis for cm-level satellite orbit determinations and mm-level ground based GPS positioning and navigation.
- Conduct global geologic and geomorphic process studies, comparative analysis, improved mapping of terrain features such as floodplains, and input to models for improvement of hazard assessment/mitigation. Conduct analysis of near-global Shuttle Radar Topography Mission (SRTM) 30-meter topographic data.

Target 1Y12: Explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities.

- Improve understanding of geodynamic processes and allow continuous observations, improved data processing efficiency and reduce operational costs by 20%. Complete the Very Long Baseline Interferometry (VLBI) Mark IV Correlator upgrade.
- Provide a basis for future tectonic modeling and earthquake vulnerability assessment. Complete installation of Southern California Integrated GPS Network (SCIGN) array of 250 precision GPS locators/receivers for monitoring strain accumulation in Southern California.

Target 1Y13: Achieve success with timely development and infusion of technologies. Enable future science missions by increasing technology readiness for mission concepts to reduce their total cost.

- Annually advance at least 25% of funded instrument technology developments one TRL.
- Develop advanced information systems technologies and concepts for processing, archival, access, and visualization of ESE data.
- Develop at least 3 technologies to demonstrate in space with the third Earth Observer New Millennium satellite.
- Transfer at least one technology development to a commercial entity for operational use.

Target 1Y14: Provide regional decision-makers with scientific and applications products/tools.

- Establish at least a second of seven Regional Earth Science Application Center (RESAC) as a self-sustaining entity.
- Improve availability of Landsat data to State and local governments by producing a digital image database of all 50 states once every two years (first of two-year cycle).
- Develop capability to assess the vulnerability of fishing grounds due to water quality issues using remote sensing and ground based information.

- Develop experimental models to demonstrate an ability to improve forecast skill levels for projecting the paths of severe storms using satellite derived sea surface winds, precipitation & surface temperature from QuikScat, TRMM, Seawinds 1A, Terra, Ocean Topography Experiment (TOPEX) and Jason-1.
- Develop a prototype capability to monitor and predict the track of at least one key atmospheric pollutant.
- Develop a predictive capability for outbreaks of malaria in Central Africa.
- Initiate two Applications Research projects with the public and private sector to develop and assess techniques to monitor and verify carbon storage in vegetation and soils.
- Develop at least two new data products for routine decision-making by user organizations involved in ESIP Cooperative Agreements and the Agriculture, Forestry and Rangeland Cooperative Agreements and Grants.

Target 1Y15: Improve access to and understanding of remotely sensed data and processing technology.

- Foster applications of remote sensing data and processing technology by involving at least 20 states in using Earth Science observations, information through informational workshops.
- Increase the operational application of remote sensing technology by initiating at least ten joint Application Research pilot projects (5-yr projects) with State and local governments addressing their specific needs as identified at planning workshops.
- Develop workforce skills needed in remote sensing, Geographic Information System (GIS), and other attending technologies by implementing at least ten active student internships at the State and local level.

Target 1Y16: Stimulate the development of a robust commercial remote sensing industry.

- Develop ten new market commercial products (e.g., oil spill containment software by EarthSat and map sheet products by Earth Resources Data Analysis System (ERDAS), Inc.), in joint commercial applications research projects.
- Identify at least one new commercial source of science data as a result of the Scientific Data Purchase activities for Earth Science research and applications.
- Develop four new validated commercial information products as a result of verification and validation partnerships with the private sector and other users through the Mississippi State Commerce Initiative and the Space Act Agreement.
- Conduct Earth Observation Commercial Applications Program (EOCAP) Technology projects that result in ten prototype products that quantify the utility of Hyperspectral and Synthetic Aperture Radar (SAR) technologies and define future market requirements.
- Increase the cost share leveraging with companies, academia and other government agencies within the EOCAP and Affiliated Research Centers (ARC) programs by 10%.

Target 1Y17: Increase efficiencies in food and fiber production with the aid of remote sensing.

- Conduct at least 30 joint applications research endeavors in conjunction with the U.S. Dept of Agriculture.

Target 1Y18: Increase public understanding of Earth system science through formal and informal education.

- Continue 90 existing grants and award 50 new graduate student research and education grants.
- Continue 17 early career grants in research/education and initiate at least two new collaborative projects in the Earth Science international young investigator program.
- Conduct at least 400 workshops training K-12 teachers of OES education products; a 13% increase over FY2000.
- Increase participating teachers in Global Learning and Observation to Benefit the Environment (GLOBE) to 13,800, and increase participating countries to 87.

Human Exploration and Development of Space Performance Targets and Indicators

Target 1H1: Complete testing and delivery for spacecraft integration of experiments for the Mars Surveyor Program 2001 orbiter and lander missions.

- Complete testing and delivery for spacecraft integration for the radiation monitoring experiment hardware (MARIE)
- Complete testing and delivery for spacecraft integration for the soil and dust analysis experiment (MECA)
- Complete testing and delivery for spacecraft integration for the Mars In-Situ Propellant Production Precursor experiment (MIP)

Target 1H2: Complete initial next decade planning mission architecture studies and technology plans.

- Complete initial next decade planning mission architecture studies

Target 1H32: Initiate the HEDS Technology/Commercialization program and establish a synergistic relationship with industry.

- Indicator is a successful response to the initial NASA Research Announcement, with a 50% cost share from industry, where appropriate.

Target 1H3: Support an expanded, productive research community to include 975 investigations annually by 2001.

- Expand support to approximately 975 investigations (from 877 reported in FY 99).
- Publish abstracts and reports of progress for over 90% of FY 2000 research investigations (tasks) and make this publication available on the Internet.
- Support publication of approximately 1500 journal articles in refereed journals.
- Support emergent microgravity research programs in biophysics and tissue engineering by selecting up to 10 new investigations.

Target 1H4: Conduct outstanding peer-reviewed and commercial research on STS 107 to advance knowledge in the fields of medicine, fundamental biology, biotechnology, fluid physics, materials processing and combustion.

- Acquire unique data to improve crew health and safety and expand understanding in biology, biotechnology cell science, fluid physics, and combustion science.

Target 1H5: Begin research on the International Space Station.

- Increase fundamental knowledge in biological and biomedical sciences and address critical questions in crew health and safety by conducting 6 to 10 ISS investigations
- Acquire unique data on colloidal self-assembly as an essential first step in the synthesis of new materials from colloidal particles.
- Measure the ISS acceleration environment, develop models to characterize the effects of that environment on ISS research, and disseminate those results to the ISS investigator community.

Target 1H6: Expedite a safety improvement program to ensure the continued safe operations of the Space Shuttle that ensures the availability of a safe and reliable Shuttle system to support Space Station Assembly milestones and operations.

- CLCS application for the Orbiter Processing Facilities is completed.

Target 1H7: Achieve 8 or fewer flight anomalies per mission.

- Achieve 8 or fewer flight anomalies per mission

Target 1H30: Achieve 100% on-orbit mission success

- Pre-flight mission/payload objective
- Post-flight mission report

Target: 1H10: Successfully complete the majority of the planned development schedules and milestones required to support the Multi-element Integration Testing

- Complete Multi-Element Integration Test II (MEIT) to include flight elements for assembly flights 8A through 12A. This will be measured by completion of five planned test configurations. MEIT Tests perform integration testing with several launch elements to increase on-orbit confidence.

Target: 1H11: Successfully complete the majority of the ISS planned on-orbit activities such as delivery of mass to orbit and enhanced functionality.

- Continue to expand the capabilities of the ISS through launch and delivery of 180,000 lbs. of hardware and logistics to the ISS.
- Initiate and demonstrate station-based Extravehicular Activity (EVA) capability to support up to 30 EVAs annually from the U.S. Airlock. This will be measured by completion of a minimum of 5 EVAs from the ISS Airlock.

Target: 1H12: Successfully complete the majority of combined ISS planned operations schedules and milestones as represented by permanent human on-orbit operations.

- Conduct permanent human on-orbit operations with an estimated 8,000 crew hours dedicated to assembly, vehicle operations and payload operations.

Target: 1H13: Successfully complete the majority of the planned research activities in support of initiation of on-orbit research opportunities.

- Initiate on-orbit research in the U.S. Laboratory focusing on early payload opportunities in the Human Research Facility (HRF-1) and four multipurpose EXPRESS Racks.
- Complete integration testing and KSC processing for the Microgravity Sciences Glovebox (MSG), refrigerator/freezer, and Window Observational Research Facility (WORF-1) in preparation for launch on UF-1 and UF-2. This will be measured by completion of schedule milestones.

Target: 1H14: Successfully complete no less than 85% of the planned Russian Program Assurance schedules and milestones required for the development of the Propulsion Module.

- Initiate Propulsion Module Fabrication/Assembly/Integration and Testing in preparation for launch in late FY 2002. This will be measured by completion of schedule milestones.

Target: 1H15: Successfully complete no less than 75% of the planned crew return capability schedules. FY01 indicators will include accomplishment of program schedule milestones for Phase 1 development of a crew return vehicle (CRV) that could provide the U.S. crew return capability.

- Complete Crew Return Vehicle (CRV) Phase 1 tasks including Preliminary Design Review (PDR). This will be measured by completion of schedule milestones.

Target: 1H17: Develop new biomedical and technological capabilities to facilitate living and working in space and return to Earth.

- Flight test countermeasure to reduce kidney stone risk
- Develop two new evidence-based health protective countermeasure candidates ready for evaluation in an operational setting.

Target: 1H18: Develop and demonstrate technologies for improved life support systems.

- Demonstrate, in ground test, technologies that could reduce up to 25% of life support logistics over ISS baseline and release report of progress for review on the Internet.
- Perform detailed calculation of life support equivalent system mass index and place online for review and comment. Equivalent system mass index is a measure of the performance of a life support system incorporating demonstrated technologies.

Target: 1H31: Initiate implementation of the Bioastronautics Initiative.

- Initiate NASA/NCI collaboration to develop minimally invasive technologies and approaches for detecting and interpreting biological signatures that signal the emergence of disease.
- Initiate expansion of the teams and tasks of the NSBRI for the development of countermeasures by adding approximately 15 investigations (NSBRI tasks).

Target: 1H20: Increase the percentage of the space operations budget allocated to acquisition of communications and data services from the commercial sector to 15%.

- Increase to 15% the space operations budget allocated to acquisition of commercial communications and data services from the 10% FY 2000 performance target.

Target: 1H21: Achieve at least 95 percent of planned data delivery from space flight missions as documented in space, ground, deep space, and NASA integrated service networks performance metrics consistent with detailed program and project operations requirements in project service level agreements.

- Achieve at least 95 percent data delivery for all space flight missions as documented in network performance metrics.

Target: 1H22: Establish at least ten new, active industrial partnerships to research tomorrow's space products and improve industrial processes through NASA's Commercial Centers, and find opportunities for space experiments

- Ensure that Commercial Centers execute ten new partnership agreements
- Monitor the ratio of flight experiments to ground experiments

Target: 1H23: Foster commercial endeavors by reviewing and/or implementing new policies and plans, such as the Space Station resource pricing policy and intellectual property rights policy. Ensure that Space Station resources allocated to commercial research are utilized by commercial partners to develop commercial products and improve industrial processes.

- Review and/or implement Space Station resource pricing and intellectual property rights policies.
- Ensure Space Station resources allocated to commercial research are utilized by commercial partners to research tomorrow's products and improve industrial processes.

Target: 1H26: Support participation in HEDS research.

- Enable at least 50 students to participate in commercial space flight and technologies research.
- Through the use of national teacher conferences and workshops, provide approximately 200 elementary and high school classrooms nationwide with electronic (multimedia/computer technologies) and printed materials that focus on activities in science, math and technology relating to life sciences and microgravity research and specifically written for students in grades K-12
- Complete a broadly based student competition on innovative design concepts that address HEDS technological challenges.
- Complete customer engagement plan

Cross-cutting target

Target: 1H29: Improve health of the NASA workforce

- Developing and implement supervisor-specific training for the identification and management of stress in the work unit. Develop and implement training on techniques for coping with stress for the individual employee.
- Begin a robust audit program of NASA Centers' occupational health programs, completing at least six (6) to ensure quality and continuous improvement of medical care and services including medical and environmental monitoring efforts, preventive services, emergency response capability, and clinical intervention capability.

Aero-Space Technology Enterprise Performance Targets and Indicators

Target 1R1: Complete 75% of the conceptual designs of systems for preventing and mitigating accidents (programmatic performance indicators are listed below), and to demonstrate tools for accident analysis and risk assessment.

Aero-Space Focused — Aviation Safety
• Conceptual designs of safety-improvement systems is completed for all projects
• Operational test of risk assessment aid: Demonstrate, in operational environment, tools for merging heterogeneous databases to aid causal analysis and risk assessment.
• Proficiency Standards: Identify flight crew knowledge and proficiency standards for automation.
• Integrated onboard health management system design: Define architecture for integrated onboard health management system.
• Concepts to limit fires: Develop proof-of-concept of technology to limit fuel flammability.
• Design criteria for low false alarm: Establish design criteria for reliable, low false-alarm fire detection systems.
• Synthetic vision retrofit concepts: Selection synthetic vision concepts suitable for retrofit in commercial, business, and GA aircraft.

Aero-Space Base R&T
• Demonstrate Intelligent Life Extending Control (ILEC) for a commercial aircraft engine through hardware in the loop simulation using component damage modeling.
• Combine Propulsion Controlled Aircraft (PCA) control laws with the Intelligent Flight Control System (IFCS) to demonstrate a new capability for adapting to absence or loss of any and all control surfaces resulting from failures or malfunctions up to and including propulsion only flight.
• Provide alloys for engine blades and disks which are more crack resistant.
• Flight validate advanced control laws and modes for reduced pilot workload and increased safety in low visibility using integrated design tool Control Designer's Unified Interfaces (CONDUIT).
• Complete report on Phase I testing of tire dynamics mechanical properties.
• Identify and evaluate existing crew strategies for reducing errors in the management concurrent tasks
• Downselect of ground-based remote sensor technologies for a prototype ground-based system to sense icing conditions.
• Issue an ultra-safe gear design guide for rotorcraft
• Demonstration of strong correlation of analytic model predictions of rotorcraft crashworthiness with full-scale water/soft-soil-impact test results
• Health and Usage Monitoring Systems (HUMS) Certification Protocols detailed for rotorcraft
• Submit documentation of certification methodology for rotorcraft composite structures analysis / certification
• Demonstration of "express-tool" technology linkage to design technologies that reduce design-to-fabrication time by 50 percent for sophisticated rotorcraft parts and assemblies

Target 1R2: Complete one system level technology benefit assessment, one component concept selection and one new material system.

Aero-Space Focused — Ultra-Efficient Engine Technology
• Select turbine flow control concept(s)

Target 1R2: Complete one system level technology benefit assessment, one component concept selection and one new material system.

Aero-Space Focused — Ultra-Efficient Engine Technology
- Select turbine flow control concept(s)
- Develop 1350°F turbomachinery disk alloy
- Define propulsion system concept(s)
- Complete selection of the most promising simulation approach for predicting propulsion-airframe integration effects for unconventional aircraft

Aero-Space Base R&T
- Complete development of heavyweight (laboratory) energy storage (fuel) cell, electrolyze, control system.
- Investigate active control of high-frequency instabilities in combustion flows
- Demonstration of "smart" panel technology with a wind tunnel test of a smart UCAV with hingeless control surfaces.

Target 1R3: Complete large scale demonstration of a 2-5 decibel reduction in aircraft noise based on 1997 production technology, and initial assessments of concepts offering additional reduction

Aero-Space Focused — Quiet Aircraft Technology
- Airframe and engine noise reduction concepts that individually or collectively show analytical potential for at least 3 decibel further reduction in noise levels.

Aero-Space Base R&T
- Full-scale static engine validation of fan and jet noise reduction concepts including active control of fan tones, and large-scale wind tunnel validation of airframe noise reduction concepts

Target 1R4: Complete the civil tiltrotor project by validating databases for contingency power, flight paths, and noise reduction, as well as complete at least one demonstration of an airspace management decision support tool.

Aero-Space Focused — Aviation Systems Capacity
- Comprehensive mission simulation database integrated cockpit and operating procedures for complex, low noise flight paths.
- Large scale database of noise reduction and validated design for noise capability.
- Develop and demonstrate transition airspace decision support tools for: (1) ATC/airline operations center and ATC/cockpit information exchange, and (2) conflict resolution.

Aero-Space Base R&T
- Demonstrate a prototype data communications scheme for the National Airspace System.

Target 1R7: Complete the Advanced General Aviation Transport Experiments project by validating transportation system concepts through flight test and publish design guidelines; establish at least one parntership agreement on Small Aircraft Transportation System program.

Aero-Space Focused — Small Aircraft Transportation System (SATS)
• Partnership agreement signed by NASA and at least one state government and one industry member
• Joint Sponsored Research Agreement signed with Virginia Space Grant Consortium partners to develop a SATSLab comprised of aircraft, airports, and airspace for validation of SATS vehicle and infrastructure features and capabilities.

Aero-Space Base R&T
• Complete the development rig test of the hot section foil bearing for a representative general aviation engine.
• Simulate and flight test validated AGATE system concepts
• Publish design guidelines; system standards; certification bases and methods
• Completed systems analysis of the benefits of STOL & ESTOL vehicles to the small aircraft transportation system.

Target 1R8: Develop at least three new design tools and accomplish at least four demonstrations of advances in computation and communications.

Aero-Space Focused — High Performance Computing and Communications
• Develop software tools to reduce parallelization time from months to one week while maintaining 50% application performance compared with manual parallelization.
• Develop tools to benchmark testbed performance in computing capability, database manipulation, and scheduling to evaluate alternate scheduling strategies and chose optimal approaches to reduce variability and improve predictability of turnaround time
• Develop automated quality of service data collection tool capable of measuring 2 service classes and scalable to at least 5 nodes
• 3 relevant application codes parallelized; 3 data analysis codes parallelized; documented evaluation of parallelization tools.
• 3X performance in an aerospace application through the integration of networking enhancements into application codes.
• 3 applications interoperating on multiple QoS enabled networks; 50Mbps (aggregate internal) multicast; gigabit performance between 2 NASA sites; 2 applications utilizing enhanced hybrid networking.
• Improvement in aerospace applications: Complete combustor and compressor simulation in 3 hours each; high-fidelity space transportation vehicle analysis in 1 week and optimization enabled; S&C database generation for aerospace vehicles within 1 week; demonstration of improvements in 4 NASA-sponsored design events.
• Assess initial HPCC technology capabilities and customer impacts.

Aero-Space Base R&T
• Develop software tools for design of advanced computing systems
• Acquire and incorporate new large-scale computing systems and demonstrate seamless operations with heterogeneous distributed computing environment.
• Demonstrate remote connectivity to high data-rate instruments and distributed real-time access to instrument data.
• Demonstrate an environment for aerospace hardware design that includes: remote connectivity and access to flight simulation data, computational simulation data and archival databases.
• Demonstrate prototype cross-fidelity aerospace design system.

• Establish experimental and analytical methodology for composite stringer pull-off failure prediction.
• Figures of merit from static wind tunnel or CFD results developed and assessed for use in predictions of uncommanded transonic lateral motions due to Abrupt Wing Stall
• Conduct turbulence modeling workshop to provide direction for turbulence modeling research to increase design confidence in flight regimes dominated by flow separation
• Conduct assessment of OAT program element impacts on goals of three pillars

Target 1R9: Demonstrate two new concepts in flight and identify three new concepts for further examination.

Aero-Space Base R&T
• Demonstrate solar-powered remotely-piloted aircraft suitable for science missions to an altitude of 100,000 feet.
• Complete development of a pulse detonated engine inlet
• Complete final validation and testing of an integrated blended-wing-body (BWB) low-speed flight research vehicle in preparation for flight in 2002.
• Complete inlet test for Pulse Detonation Engine application
• Complete second flight of Hyper-X (X-43) at Mach 7
• Complete flight testing of Hyper-X (X-43) at Mach 10.
• Complete an integrated blended-wing-body (BWB) low-speed flight research vehicle prepared and delivered for final validation and testing.
• Identify advanced vehicle concepts for further research
• Demonstrate robust taxi capability with contingency planning for an autonomous vehicle
• Complete 60% of planned experiments on the F-15B testbed aircraft

Target 1R10: Complete assembly of the third X-34 test vehicle, demonstrate 75% of supporting technology developments, and complete competitive solicitations for expanded 2nd generation reusable launch vehicle efforts.

Aero-Space Focused — X-33
• A performance indicator for the X-33 is not possible until the liquid hydrogen tank delamination investigation and program impact assesment are complete.

Aero-Space Focused — X-34
• Complete the third X-34 (A-3) vehicle assembly.

Aero-Space Focused — Future-X
• The integrated vehicle health monitoring system flight experiment is delivered for installation in the X-34

Aero-Space Focused — 2nd Generation RLV Focused
• Award multiple industry contracts for Systems Engineering and Requirements Definition, RLV Competition and Risk Reduction and NASA Unique Systems program elements

Aero-Space Base R&T
• Complete assessment and preliminary design of Pulse Detonation Engine-based hybrid cycle and combined-cycle propulsion systems.
• Complete Phase 1 modifications of the Numerical Propulsion Simulation System to allow analysis of a rocket and a rocket-based-combined-cycle propulsion systems
• Identify protocols and test methods needed for accelerated testing of space transportation vehicle materials
• Extrude near-net thin walled sections of Russian alloy 1441 for aerospace applications
• Complete RLV focused composite cryogenic tank and structures technologies
• Combined Cycle Engine System Selected for first Flight Demonstrator
• Combined Cycle Flowpath Definition and Testing Completed for First Flight Demonstrator

Target 1R11: Commence X-37 vehicle assembly, and complete one Pathfinder flight experiment.

Aero-Space Focused — Future-X
• Commence X-37 vehicle assembly
• ProSEDS evaluation completed
• Flight of Hall Effect Thruster experiment

Target 1R12: Continue the solicitation of customer feedback on the services, facilities and expertise provided by the Aero-Space Technology Enterprise

Triennial Customer Survey
• Complete the Triennial Customer Satisfaction survey, and maintain a "highly satisfied" rating from 35 percent of Enterprise customers.

Facility Utilization Survey
• Achieve a facility utilization customer satisfaction rating of 95 percent at "5" or better, and 80 percent "8" or better ,based on exit interviews.

Technology Transfer
• Transfer at least twelve new technologies and processes to industry during the fiscal year.

Target 1R13: Continue the implementation of current education outreach plans, and establish new plans for all new program activities initiated in FY 01.

Education Outreach
• Implementation examples from current education outreach plans.
• Documented plans for all new program activities initiated in FY 2001.

Manage Strategically Performance Targets and Indicators

Target 1MS1: NASA will increase the safety of its infrastructure and workforce with facilities safety improvements, reduced environmental hazards, increased physical security, and enhanced safety awareness among its employees.

- Per President Clinton's direction under the Federal Worker 2000 Presidential Initiative, reduce the overall occurrence of injuries (due to occupational injury or illness) by 3% per year from the FY 97 baseline to 1.15 occurrences per 100 workers
- Award of construction contract(s) for all identified critical facilities safety requirements as specified in the Agency Annual Construction Program.
- Award/modification of all planned contracts for physical security upgrades to NASA's Minimum Essential Infrastructure defined in the NASA Critical Infrastructure Plan.
- Reduced incidences of environmental mishaps or non-compliance from the FY2000 baseline year by 5%.
- Exceeding the FY 99 baseline for NASA's aggregate safety Performance Evaluation Profile (PEP).

Target 1MS2: Continue to take advantage of opportunities for improved contract management by maintaining a high proportion of Performance Based Contracts (PBC's), and maintain significant contractor involvement in NASA programs of small businesses, minority institutions, and minority and women owned businesses.

- Maintaining PBC obligations at 80% of funds available for PBC's (funds available exclude grants, cooperative agreements, actions under $100,000, SBIR, STTR, FFRDC's, intragovernmental agreements, and contracts with foreign governments or international organizations)
- Achieving at least an 8% goal for annual funding to small disadvantaged businesses (includes funding for prime and subcontracts awarded to programs supporting small disadvantaged businesses, historically Black Colleges and Universities, and other minority institutions, and women-owned small businesses

Target1MS3: Renew Agency's management systems, facilities, and human resources through updated use of automated systems, facilities revitalization, and personnel training.

- Cost at least 75% of the resources authority available to cost during the fiscal year.
- Completing installation of the Budget and Core Accounting Integrated financial Management System at NASA's remaining field locations.

- Maintain a diverse NASA workforce wherever women, minorities, and persons with disabilities are represented at levels equal to or greater than their FY99 levels, with a target of increasing representation of minorities by at least one percent per year, women by at least one percent per year, and persons with disabilities by at least .5 percent per year.
- Increasing training opportunities in technology-based learning by 10%
- Increasing by 20% employee use of technology-based learning opportunities.
- Using FY 01 budgeted funds for awarding construction contracts toward reducing the Agency's estimated $1.4B facilities revitalization needs.
- Implement 60% of the identified Environmental Compliance and Restoration projects to reduce and manage the Agency's $1.1B future unfunded environmental liability .

Target 1MS4: Improve IT infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory," and enhance IT security through reduction of system vulnerabilities across all NASA centers, emphasizing IT security awareness training for all NASA personnel.

- Improve IT infrastructure service delivery to provide increased capability and efficiency while maintaining a customer rating of "satisfactory" and holding costs per resource unit to the FY 98 baseline. (Note: Measurements are of processing capability in millions of instructions per second, bits of information processed per second, the per second cost of the preceding capacity, and customer feedback ratings on service requests as well as annual surveys of principal users.)

- (b) Enhance IT security through reduction of system vulnerabilities across all NASA Centers and through emphasis on IT security awareness training for all NASA personnel.

Provide Aerospace Products and Capabilities Performance Targets and Indicators

Target 1P1: Meet schedule and cost commitments by keeping development and upgrade of major scientific facilities and capital assets within 110% of cost and schedule estimates, on average.

- Meet schedule and cost commitments by keeping development and upgrade of major scientific facilities and capital assets within 110% of cost and schedule estimates, on average.

Target 1P2: Establish prototype collaborative engineering environments focused on the representative set of enterprise applications and evaluate performance against non-collaborative benchmarks.

- Readiness test of prototype will be completed.
- Performance of prototype will be measured against benchmarks.

Target 1P3: Ensure the availability of NASA's spacecraft and facilities by decreasing operating time lost to unscheduled downtime.

- Ensure the availability of NASA's spacecraft and facilities by decreasing operating time lost to unscheduled downtime, relative to FY00 availability.

Target 1P4: Capture a set of best practices/lessons learned from each Program, to include at least one from each of the four PAPAC subprocesses documented in NPG 7120.5, commensurate with current program status. Data will be implemented in PAPAC process improvement and in Program/Project Management training.

- A set of best practices/lessons learned will be captured from each Program, to include at least one from each of the four PAPAC subprocesses, commensurate with current program status. Data will be implemented in PAPAC process improvement and in Program/Project Management training.

Target 1P5: Dedicate 10 to 20 percent of the Agency's Research & Development budget to commercial partnerships.

- Dedicate 10 to 20 percent of the Agency's Research & Development budget to commercial partnerships.

Target 1P6: Dedicate the percent of the technology budget that was reported in the FY00 Performance Report toward leveraging with activities of other organizations.

- Dedicate the percent of the technology budget that was reported in FY00 toward leveraging with activities of other organizations.

Generate Knowledge Performance Targets and Indicators

Target 1G1: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will obtain scientific guidance from their investigator communities.

- At least seven letters of advice will be received from the enterprises' FACA-chartered advisory committees.

Target 1G2: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will develop and/or release updated enterprise strategic plans.

- The Space Science Enterprise and the Earth Science Enterprise will release new enterprise strategic plans, and OLMSA/HEDS will review its new strategic plan with their advisory bodies.

Target 1G3: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use competitive merit review wherever possible to select performers for science and basic technology research.

- Taken together, the Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will use AOs, NRAs, and Cooperative Agreement Notice solicitations to award 80 percent or more of science and basic research funds via merit competition.

Target 1G4: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will disseminate results of their research to a diverse population of users, including education users and the general public.

- Research programs of the Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS, taken together, will account for 5 percent of the 150 "most important stories" in the annual review by *Science News*. The three enterprises will achieve their individual indicators in education and public outreach and publication of research progress. The three enterprises will maintain and periodically update publicly accessible web sites for active missions.

Target 1G5: The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will make science data obtained widely accessible as soon as possible after receipt and will maintain these data in open archives.

- The Space Science Enterprise, the Earth Science Enterprise, and OLMSA/HEDS will achieve their specific individual indicators for ensuring mission data maintenance and access.

Target 1G6: Work with other federal agencies and U.S. industry to complement and support our activities.

- Establish and implement MOUs and MOAs with U.S. Federal agencies and industry for appropriate partnerships in research areas of shared interest.

Target 1G7: Pursue mutually beneficial cooperative activities in aeronautics and space with other nations.

- Establish and implement LOAs and MOUs for appropriate partnerships with foreign space agencies for cooperative activities.

Communicate Knowledge Performance Targets and Indicators

Target 1CK1: Convey information about, and knowledge generated by NASA's programs, to the public

- Support no less than 800 portable exhibit loans and send portable exhibits to a minimum of 175 targeted events per year. Some of the NASA Centers have Internet sites that provide information about their exhibit loan programs. By the end of FY 01 all of the Centers will have this on-line resource.
- Track public attendance and participation in NASA's Fine Arts Program increasing viewership by 10 percent per year of NASA art and by reaching 40 states by the end of FY 2001.
- Increase the baseline for live satellite interview programs to no less than 15 live shots per month (on average), by facilitating astronauts, program managers and other Agency officials for live satellite interviews via NASA Television.
- Increase the NASA-sponsored, funded, and/or generated report documents for the scientific community and public to 14,059.
- Increase the nontraditional NASA-sponsored scientific and technical information through the NASA Image Exchange (NIX) digital image database to more than 550,000 in FY01.
- Produce 10 new historical publications chronicling and placing NASA's activities and achievements in perspective for the American public.

Target 1CK2: Assist the public and customers to locate and retrieve information on, or that has been generated by, a NASA program

- Provide the public with quick service by assisting 98% of customers who use the Scientific Technical Information and the NASA Image Exchange Help Desks within a specific turnaround period of 3 days. (1CK2a)
- Make the NASA web pages as accessible to the public as possible. The goal is to increase the number of searched pages by 5 percent per year. (1CK2b)
- Increase the capacity of NASA's Home Page to meet public demand. The goal is to continue to provide for a 5 percent per year increase in download demand, 834,700 web pages were downloaded weekly in 1999.

Target 1CK3: Facilitate the transfer of NASA generated technology and innovations to private industry

- Increase new opportunities to transfer technology developed at NASA to private industry to 20,100. Opportunities will be made available to the public through the NASA TechTracs database and will be accessible through the Internet.
- Produce two industry-specific editions of *Aerospace Technology Innovations* publication in FY 2001.
- Provide publications that will communicate NASA technologies available for commercial use or that have already been commercialized. Print subscriber/distribution metrics are; *Aerospace Technology Innovations*, - 12,500, *Spinoff* - 51,000, and *Tech Briefs* - 210,000.

Target 1CK4: Support educational excellence and reach out to the underserved and underrepresented minority community

- With the increased level of funding provided in the FY 2001 President's Budget, NASA will be able to maintain education program level with participant involvement of approximately 3 million teachers, faculty, and students in the education community.
- Ensure that the NASA education program is meeting customer's needs by maintain an "excellence" rating of at least 4.3 on a 5.0 scale, as rated by those customers.
- After a 2 year flat budget, the increased funding provided in the FY 2001 President's Budget will enable NASA to increase the number of sites that offer pre-college Science, Engineering, Mathematics, and Aeronautics Academy curriculum by 2 from FY 1999.
- Produce 3 refereed papers or book chapters for each $100,000 of research funding provided through the Minority University Research & Education Program.