National Aeronautics and
Space Administration

# Budget Estimates

# Fiscal Year 1998

Agency Summary

Human Space Flight

Science, Aeronautics and Technology

Mission Support

Inspector General

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## USEFUL NASA WEBSITES

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| NASA | http://www.nasa.gov/ |
| 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://www.hq.nasa.gov/office/codeb/Welcome.html |
| Budget Request | http://www.hq.nasa.gov/office/codeb/budget/ |
| Accountability Report | http://www.hq.nasa.gov/office/codeb/ANN-REPT/contents.htm |
| Public Affairs | http://www.gsfc.nasa.gov/hqpao/hqpao_home.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/ |
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| Aeronautics Enterprise | http://www.aero.hq.nasa.gov/ |
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| Office of Space Flight | http://www.osf.hq.nasa.gov/ |
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| Space Science Enterprise | http://www.hq.nasa.gov/office/oss/ |
| Ames Research Center | http://www.arc.nasa.gov/ |
| Dryden Flight Research Center | http://www.dfrc.nasa.gov/dryden.html |
| Goddard Space Flight Center | http://www.gsfc.nasa.gov/ |
| Wallops Flight Facility | http://www.wff.nasa.gov/ |
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| Jet Propulsion Laboratory | http://www.jpl.nasa.gov/ |
| Johnson Space Center | http://www.jsc.nasa.gov/ |
| Kennedy Space Center | http://www.ksc.nasa.gov/ksc.html |
| Langley Research Center | http://www.larc.nasa.gov/larc.cgi |
| Lewis Research Center | http://www.lerc.nasa.gov/LeRC_homepage.html |
| Marshall Space Flight Center | http://www.msfc.nasa.gov/ |
| Stennis Space Center | http://www.ssc.nasa.gov/ |
| NASA Advisory Council | http://www.hq.nasa.gov/office/codez/nac.htm |

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**FISCAL YEAR 1998 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:

- Explore, use and enable the development of space for human enterprise;
- Advance scientific knowledge and understanding of the Earth, the Solar System, and the Universe and use the environment of space for research;
- 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 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.
- Preserving the Environment - NASA studies the Earth as a planet and as a system to understand global 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.

To fulfill NASA's mission of exploration. discovery arid innovation, NASA sets the following overarching goals to take its science and aeronautics program proudly into the 21st century:

- NASA will be at the forefront of exploration arid science. We will develop and transfer cutting-edge technologies in aeronautics and space. NASA will establish a permanent human presence in space.
- As NASA pursues is mission, NASA will enrich the Nation's society and economy. NASA will contribute to a better life for this and future generations.
- In the coming decades, it is our goal to undertake bold and noble challenges -- exciting future programs, such as the return of humans to the Moon and human missions to Mars, which stir the imagination and fall within the grasp of the United States and its international partners' technical and financial grasp.

The President's civil space policy, released in September 1996, underscores NASA's role as the lead Federal agency for civil space R&D. It features NASA's strengthening of its focus on cutting edge R&D and deemphasis on operational activities. The policy highlights priorities in human space flight (permanent human presence in space), science (Earth observation, continuous robotic presence on Mars surface, celestial sample returns and search for other Earth-like planets), and space technology (reuseable launch vehicles and smaller, cheaper space missions). It also underscores NASA's leveraging of industry through purchases of launch services, spacecrafts, data products, communication services, and new technology; and continued close coordination with DoD and NOAA.

## STRATEGY FOR ACHIEVING OUR GOALS

The framework for achieving these goals is embodied in the NASA Strategic Plan, which separates key NASA activities into four distinct Strategic Enterprises. They are:

- Mission to Planet Earth;
- Aeronautics and Space Transportation Technology;
- Human Exploration and Development of Space; and,
- Space Science;

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 the cost and technical risk. At the same time, there is considerable synergy between the Enterprise activities which strengthens the activities of each. A broad description of the focus of each Strategic Enterprise follows:

**Mission to Planet Earth** - The activities which 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 which will be needed indefinitely, 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 Mission to Planet Earth Enterprise is developing the understanding needed to support the complex environmental policy decisions that lie ahead.

**Aeronautics and Space Transportation Technology** - 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. Future U.S. competitiveness in aeronautics and access to space, including the continued safety and productivity of the Nation's air transportation system, is dependent upon sustained NASA advances in aeronautics research and technology. Activities pursued as part of this Enterprise emphasize customer involvement, encompassing U.S. industry, the Department of Defense, and the Federal Aviation Administration.

The Space Transportation Technology program will develop new technologies aimed at revitalizing access to space. The technologies targeted will reduce launch costs dramatically over the next decade, increase safety and the 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. The Reuseable Launch Vehicle (RLV) program is pursuing technology development and concept definition activities in support of next-generation reuseable launch systesm. The Advanced Space Transportation Program is developing key technologies to dramatically reduce space transportation costs across the mission spectrum. particularly advances with the potential of reducing launch costs beyond RLV goals. Programs in support of the effective transfer of NASA technology to the commercial sector are included in this Enterprise.

**Human Exploration and the Development of Space** - Human Space Flight serves as a foundation for much of what NASA does. Activities pursued as part of the Human Exploration and Development of Space Enterprise seek to bring the frontiers of space fully within the sphere of human activities for the benefit of America and all humankind in this and future generations. It will open the space frontier by exploring, using, and enabling the development of space. NASA was propelled into the space frontier, by an international political challenge born of the Cold War. With the Cold War behind us, we seek to work with other nations in our current and future activities, and to lay the foundations for human development of space.

**Space Science** - The activities of the Space Science Enterprise seek answers to fundamental questions, such as understanding the origin of the universe and our solar system, how they have evolved, and whether the Earth is unique, if there are planets around other stars 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.

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 in NASA in the National Aeronautics and Space Act in 1958, and the benefits remain strong today.

## PLANS AND ACCOMPLISHMENTS

The NASA budget request for FY 1998 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 Space Station arid flight support for cooperative programs with Russia:

**Science, Aeronautics and Technology** - providing funding for NASA's research arid development activities, including all science activities, global monitoring, aeronautics, technology investments, education programs, mission communication services and direct program support:

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

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

The NASA Space Science program has achieved impressive successes this past year -- possible indications of primitive life **on** Mars; new discoveries about the origin of the universe: identification **of** planets around neighboring stars: and intriguing possibilities of liquid water on Jupiter's moon Europa. To capitalize on these enormous successes during the past year, the NASA budget request for FY 1998 highlights the Origins program. The Origins program is focused on answering fundamental questions regarding the creation of the universe and planetary systems and the possibility of life elsewhere beyond Earth. A strategy for addressing these questions would involve returning surface samples from Mars; visiting comets and other planetary bodies; arid deploying powerful telescopes to detect Earth-like planets elsewhere in our galaxy. NASA's Origins program is responsive to the President's new civil space policy and is a vital component of the Administration's investment strategy in science and technology.

The NASA budget request for FY 1998 continues the commitment by the President 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 Space Policy, issued in September 1996, 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 1998 is fully supportive of these goals.

The emphasis on cheaper, more capable science missions is continued in the FY 1998 budget request. These programs experiment with new innovative management and procurement practices, promote smaller affordable missions and enforce strict adherence to perforniance criteria and a cost cap.

- The Discovery program reflects NASA's commitment *to* ensuring a continuous stream of new planetary science data and more frequent access to space. The first two Discovery missions, the Near Earth Asteroid Rendezvous (NEAR) mission and the Mars Pathfinder, were launched in 1996. The next Discovery mission, Lunar Prospector, is scheduled for launch in September 1997.
- The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. The first mission, the Mars Surveyor mission, was launched in November 1996. The second series of Mars Surveyor spacecraft will be launched during the next launch opportunity in December 1998 and January 1999.
- The New Millennium Spacecraft program is an aggressive technology development and demonstration program underway that is designed *to* precipitate a revolution in the design, development and implementation of science spacecraft and instruments. Initiatives are underway in the Office of Space Science and the Mission to Planet Earth to identify. develop and flight validate a new generation of technologies. Technologies for the first two Space Science New Millennium missions have been selected and development has begun. **An** advanced land imager has been selected as the first Mission to Planet Earth mission in the New Millennium program. Future technologies will be identified for development that reduce cost or improve perforniance of future Earth Observing spacecraft.
- The Earth System Source Pathfinder (ESSP) is a science driven prograin intended *to* identify and develop small satellite missions *to* accomplish scientific objectives in response to national and international research priorities not addressed by current programs. The first ESSP mission is scheduled for selection in early 1997.

In order to achieve significant savings in the cost **of** space missions, the cost of going to orbit must be reduced by orders of magnitude. The Reusable Launch Vehicle program **is** addressing, in partnership with the private sector, the new and innovative technologies that are needed to meet the challenges and lower the costs **of** future space missions. Phase II of the **X-33** program, encompassing both ground and flight tests, is underway, and is expected *to* lead to a decision by the government and our industry partners whether full-scale development of an RLV should be pursued. This program utilizes an innovative management approach, based on industry-led cooperative agreements. The government is acting as partners and subcontractors. reporting costs and manpower to the industry team leader as would any other subcontractor. This approach allows a much leaner managemerit structure, lower program overhead costs and increased management efficiency.

NASA's ability to inspire arid expand the horizons of present and future generations rests on the success of these efforts *to* maintain this nation's leadership in space within the reality of the fiscal constraints facing the federal budget. In order *to* ensure the stability to manage and execute programs within budget and schedule, **NASA** is seeking multi-year appropriations for selected space projects -- the International Space Station, the Space Infrared Telescope Facility (SIRTF), the Stratospheric Observatory for Infrared Astronomy (SOFIA). the **X-33.** and the 'Tracking and Data Relay Satellite (TDRS) Replenishment spacecraft.

NASA has been at the forefront of the Administration's efforts to reshape the federal government, to make it smaller, cut costs, and be more responsive to the ultimate customer, the taxpayer. During 1996, recommendations from the Zero Base Review continued to be implemented and real infrastructure changes were made to meet NASA's commitment to lower budget runout targets.

- A single Shuttle contractor was implemented at the Kennedy Space Center in October 1996;
- NASA's civil service workforce was reduced an additional 618 full time equivalents over the FY 1996 baseline of 21,555. Total civil service employment for NASA at the end of FY 1996 was 20, 937 full time equivalents.
- Center Missions and Centers of Excellence identified for each of the NASA field centers in the Zero Base Review, continued to be put into place. These Center Missions and Centers of Excellence map directly to NASA's Strategic Enterprises and provide a direct relationship to the way each Center supports NASA's goals. In 1996, NASA transitioned its management practices to reflect this approach. The leaders of each Enterprise at Headquarters will provide the strategy for each area consistent with the NASA Strategic Plan. The responsibility and accountability for program implementation will be at the NASA field centers.
- Buildings and facilities continued to be closed during FY 1996. The replacement value of facilities closed through FY 1996 is $1.5 billion.

NASA continues to be a leader in responding to the challenge of reducing the federal deficit and the goals of the National Performance Review. Over the past several years, NASA has undergone a thorough scrutiny of its mission, organization and activities. The Zero Base Review, which involved a difficult introspective examination of NASA's activities and workforce, resulted in recommendations which are being implemented at every NASA field center, including Headquarters. A strengthened program management system has been implemented and the Program Management Council regularly reviews the technical, schedule and financial status of NASA's major activities. A disciplined process has been established for the early identification of problems, and guidelines for addressing a solution. This process has resulted in senior management attention focused on program performance. The FY 1998 budget proposes mulit-year appropriations for development of the Space Infrared Telescope Facility (SIRTF), the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the X-33 Experimental Launch Vehicle technology demonstrator. The multi-year funding will ensure the stability to manage and execute these programs within their budget and schedule commitments. A new Strategic Management process has been put in place to provide a continuous process for NASA to make critical decisions about its long-term goals, near-term activities, and institutional capabilities that are in alignment with customer requirements. A fundamental goal of NASA's Strategic Management process is to ensure that the Agency provides its customers with excellent products and services in the most cost-effective and timely manner.

## HUMAN SPACE FLIGHT

This appropriation encompasses all human space flight activities, including development of the Space Station and the safe and efficient operation of the Space Shuttle. The International Space Station is the culmination of the redesign work begun in FY 1993 to reduce program costs while still providing significant research capabilities. Space Station partners include NASA, the Russian Space Agency (RSA), European Space Agency (ESA), the Canadian Space Agency (CSA), and the National Space Development Agency of Japan (NASDA). The partnerships significantly enhance the capabilities of the International Space Station, and ensure compatible interfacing elements. The program is led by a single contractor, Boeing, which has total development and integration

responsibilities. A streamlined program office at the Johnson Space Center has primary management responsibility for the program, and is structured around integrated product teams with responsibility for bringing the systems and elements into integrated launch packages.

The Administration continues to be strongly committed to development of the International Space Station, and the preservation of the partnerships between the United States, Russia, Europe, Japan and Canada. The proposed budget provides multi-year funding for the complete development of the Station within the $2.1 .billion ceiling and the $17.4 billion development constraints, with Station assembly beginning in late 1997 and finishing by 2002. The Administration continues to monitor progress through this crucial development period and will consider future funding, schedule, or content adjustments if they prove necessary to minimize program costs, maintain international participation, and ensure a Station capable of continuous scientific and technological research and permanent human presence in space. During the past year, the Space Station program has focused on the continued qualification testing and manufacture of flight hardware as the program readies for first element launch in November 1997. Production of flight hardware continued in earnest during FY 1996. At the end of 1996. nearly 140,000 pounds of flight hardware had been completed. Major work has been completed on the FGB. the nodes, U.S. laboratory, and the subsystems needed for outfitting. The program has completed a system-level preliminary design review for the hardware and systems necessary for the first six U.S. flights, as well as preliminary design reviews for flights six through twelve. International efforts continued with negotiations on the lntemational Space Station agreements to reflect the addition of Russia to the partnership. Agreement was reached between NASA and the Russian Space Agency on the Memorandum of Understanding. The International Space Station partners are well into the manufacturing phase for their hardware contributions.

During FY 1997, the major program focus will be manufacturing and testing flight hardware to support first element launch (FEL) in November of 1997 and subsequent launches throughout early 1998. Major preparation will be made in support of the FGB, node 1, truss segments, the U.S. laboratory, and the subsystems to support these elements. The international partners will continue development of flight hardware with the functional cargo block (FGB) flight article assembly completion and delivery to Baikanour, the start of the Space Station remote manipulator system (SSRMS) perforniance test, and the Japanese Experiment Module (JEM) critical design review (CDR)-2 . The Mission Control Center (MCC) at the Johnson Space Center (JSC) will be the prime site for the planning and execution of integrated system operations of the Space Station, with exclusive command and control authority. The MCC at JSC and the MCC at Kalingrad form the unified command and control center for the Space Station. The Marshall Space Flight Center (MSFC) has responsibility for the payload integration and operations process. The payload integration process has been streamlined and shortened significantly from procedures used on the Space Shuttle. Standardized payload accommodation and an express rack concept have been incorporated for later payload manifesting. A Payload Operations Integration Center and user support facilities will be located at the MSFC as part of existing facilities that support the Shuttle/Spacelab activities.

Beginning in FY 1998, funding for all elements of the $2.1 billion Space Station program is included in the Human Space Flight appropriation. This will allow maximum flexibility in providing a balanced program, especially as program activities intensify in support of FEL. Program elements now included in the International Space Station budget are: Space Station Development, Operations, and the Research Program, including research facilities under development by the Offices of Life and Microgravity

Sciences and Applications and the Mission to Planet Earth and the flight support component of the Russian cooperation program to Mir. Program reserves are being closely monitored to maintain as high a level as possible to address technical issues that are expected to inevitably occur during this peak period of Space Station engineering and developnient.

The highest priority of the Shuttle program remains the safe launch, operation and return of the orbiter and crew. Funding is included to continue modifications that will significantly improve the Space Shuttle's overall safety, including modifications to the Main Engine and the Orbiter, as well as to initiate a program of upgrades to increase reliability and maintainability. In addition, funding for investments to improve Shuttle performance, such as the Super Lightweight External Tank, is included in order to satisfy space station requirements. Transition to a consolidation of Space Shuttle operations contracts into a single prime contractual arrangement was accomplished in October 1996. Transition activities will continue over the next 2 years. It is expected that this consolidation will achieve the challenge of finding additional cost savings in the outyears. These savings have been incorporated into NASA's budget planning.

During 1996, valuable experience was gained in docking procedures during three Space Shuttle flights to the Russian Space Station Mir. U.S. astronauts maintained a continuing presence on the Mir, highlighted by the record setting stay of 181 days by astronaut Shannon Lucid. This experience is allowing NASA to gain valuable experience in the long term effects of weightlessness, as well as allowing the United States and Russia to work closely together in as Space Station partners. In 1997. an American astronaut will be continuously on board the Mir Space Station, performing scienctific experiments. Currently, nine joint U.S. visits to the Mir are planned, which will provide approximately 24 months of on-orbit time to test science hardware planned for the Space Station. In FY 1996 and in FY 1997, American astronauts will spend 12 months aboard the Mir conducting research. U.S. - Russian cooperation in space and aeronautics extends across the NASA programs.

The Space Shuttle continues to provide its unique capabilities. In FY 1996, eight missions were completed, including three missions to the Mir Space Station. Seven missions are planned for FY 1997, including three missions to the Mir Space Station and a Hubble Space Telescope servicing mission. Seven missions are planned for FY 1998, including the first assembly flights for the International Space Station, the final two flights to the Mir Space Station and the AXAF deployment. Spacelab flights focusing on life sciences and materials sciences will be conducted during FY 1997 in preparation for operations using the International Space Station. The Spacelab program will terminate in FY 1998 following the Neurolab mission.

## SCIENCE, AERONAUTICS AND TECHNOLOGY

### Space Science

The Space Science program is designed to expand our scientific understanding of the Sun, solar system, and universe beyond Planet Earth. It seeks answers to fundamental questions, such as understanding the origin of the universe and our solar system, how they have evolved, and whether the Earth is unique; if there are planets around other stars; and, if life exists elsewhere. In 1996, several scientific discoveries rocked fundamental theories and opened discussions of long-held beliefs. The discovery of

evidence in a meteorite believed to come from Mars that may indicate life began on Mars early in its history; the discovery of a possible subsurface ocean on Jupiter's moon Europa; and the possible discovery of deep frozen lakes on the south pole of the Earth's moon are among the highlights. To capitalize on these enormous successes the past year, the NASA budget request for FY 1998 highlights the Origins program. The Origins program is focused on answering fundamental questions regarding the creation of the universe and planetary systems, and possibility of life elsewhere beyond Earth. A strategy for addressing these questions would involve returning surface samples from Mars; visiting comets and other planetary bodies; and deploying powerful telescopes to detect Earth-like planets elsewhere in our galaxy. NASA's Origins program is responsive to the President's new civil space policy and is a vital component of the Administration investment strategy in science and technology.

The Space Science program has assumed management responsibility in the FY 1998 budget for those elements of the Spacecraft and Remote Sensing program which support unique space science technology requirements, and which develop crosscutting technology for future space science, Earth observing, and human exploration spacecraft systems. These new technologies are expected to reduce costs and increase preformance to enable new and more flexible niissions for all of NASA's enterprises. This program was formerly conducted by the Office of Space Access and Technology, which was disbanded in 1996. Program elements specific to other NASA programs were transferred to those offices.

The Space Science program continues a robust program of flight development activities. The first two Discovery missions, the Near Earth Asteroid Rendezvous (NEAR) mission and the Mars Pathfinder were launched in 1996, both on Delta II launch vehicles. A Discovery mission development cost (phase C/D through launch plus 30 days) must be less than $150 million (FY 1992 dollars) and the mission must be launched within 3 years from start of development. These missions are designed to ensure a continuous stream of new planetary science data and more frequent access to space - both of which are critical requirements for a robust science program in the future. Funding is included to continue the Discovery program, with the next mission, the Lunar Prospector mission, planned for launch in September 1997. The first spacecraft in the Mars Surveyor'program, Mars Global Surveyor, was launched in November 1996. Funding for the Mars Surveyor Program, initiated in FY 1995 continues. Mars Surveyor is a series of small missions designed to resume the detailed exploration of Mars following the loss of the Mars Observer mission in 1993; subsequent missions are to be launched at two year intervals, due to the orbital periods of Earth and Mars. Funding is included to complete development activities and begin flight operations on the Cassini mission to Saturn, scheduled for launch in October 1997 on a Titan IV launch vehicle. Development activities on the Advanced X-ray Astrophysics Facility (AXAF) continue, with launch by the Shuttle scheduled for August 1998. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, the AXAF will provide unique and crucial information on the nature of objects ranging from nearby stars like our sun to quasars at the edge of the observable universe. Definition activities on the final "Great Observatory", the Space Infrared Telescope Facility (SIRTF) are planned for completion in FY 1997; funding to initiate development of the spacecraft is included for FY 1998. The other "Great Observatories", include the Compton Gamma Ray Observatory. the Hubble Space Telescope, and the AXAF.

Funding is requested to continue the New Millennium Program, which will develop and demonstrate revolutionary new spacecraft technologies to enable more frequent, less costly missions on smaller spacecraft. This program is addressing key technology advancements -- including communications, navigation and attitude control, power, propulsion. avionics, instrumentation, rover

technologies, operations and ground control. The smaller, more intelligent, less expensive spacecraft resulting from these technology advancements will not only revolutionize NASA's exploration programs, but have beneficial payoffs for the commercial spacecraft industry as well. Funding is included for continued development of the first two technology demonstrations missions, Deep Space (DS)- 1 and DS-2, as well as definition of future New Millennium missions. Independent Product Development Teams and Science Working Groups have been selected and are developing roadmaps and selected technologies for the Deep Space missions. Funding is initiated in FY 1998 to support development of revolutionary technologies required for a new generation of outer planetary missions, with an ultimate goal of a "spacecraft on a chip". These new technologies are regarded as too high risk for industry investment at this stage in their development and include advanced microelectronics and avionics, power generation, micro-devices, and telecommunications, all to be designed and fabricated on a single chip as opposed to larger subsystem "black boxes". Funding is also included, within the Space Science Supporting Research and Technology program, beginning in FY 1998, to undertake an aggressive technology development effort to enable new missions to the outer planets, and to search for Earth-like planets around nearby stars. New technologies are also being pursued to enhance our capability to explore our own **Solar** System robotically, and perhaps to confirm the past or current presence of life on other planets or their moons.

Funding is included in FY 1997 to complete final definition and preliminary design of the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) mission and to initiate hardware development: funding is included in FY 1998 to continue hardware development toward a targeted launch date in January 2000.

Funding is also included for the continued development of the Gravity Probe-B mission and for Explorer missions, which conduct investigations of an exploratory or survey nature, as well as for a number of instruments and payloads to be used on international satellites or on Spacelab missions. In Explorers, the Fast Auroral Snapshot (FAST) mission was launched in August 1996. Development activities continue on the Advanced Composition Explorer (ACE) for launch in 1997 and on the Far Ultraviolet Spectroscopy Explorer (FUSE) for launch in 1998. Selection of a prime contractor to develop and operate the Stratospheric Observatory for Infrared Astronomy (SOFIA) was made in early FY 1997. SOFIA is a cooperative program with Germany that will replace the retired Kuiper Airborne Observatory. (KAO). Together with data from the Hubble Space Telscope (HST) and the SIRTF, these programs will launch a new era in infrared astronomy.

Results from the refurbished HST continued to dominate the world of astronomy through 1996. The results from Hubble continue to touch on some of the most fundamental astronomical questions of the 20th century, including the existence of black holes, the age of the universe and the formation of planets around stars. Funding for the science data management, archiving, and science networking is continued. Funding is included to support ongoing servicing support and new instrument development for the HST. The HST Imaging Spectrograph (STIS) and Near Infrared Camera and Multi-object Spectrometer (NICMOS) are being developed for the second servicing mission, scheduled for flight in 1997. Funding is included to continue development of the Advanced Camera for flight in 1999.

Results from initial data received from the Galileo mission to Jupiter are challenging scientists to reexamine long-held theories on the environment of this largest planet in our solar system and providing startling new details concerning Jupiter's moons. Galileo's atmospheric probe was released in July 1995 and successfully entered Jupiter's atmosphere shortly before Galileo was successfully inserted into Jupiter orbit December 7, 1995. The Orbiter is partially through its 23 month study of the Jovian

system. and will orbit the giant planet 11 times. Galileo completed the return of the probe data as well as new science and images from Jupiter and encounters with the four Galilean satellites, Io. Ganymede, Europa and Callisot in 1996. Among the most important discoveries are:

- the intrinsic magnetic field and probable iron core of Io;
- the intrinsic magnetic field of Ganymede
- the lack of an intrinsic magnetic field on Callisto: and,
- evidence that Callisto's interior is undifferentiated.

In situ measurements during the Galileo probe's descent into Jupiter's atmosphere in December 1995 produced a wealth of results. The most significant are that there is much less water vapor than expected, and that winds persist much deeper into the atmosphere than expected. Galileo has also provided images of Europa that indicate the possibility of liquid water on that moon. Additional information on Europa will be provided in the data from the December 1996 Galileo fly-by, the closest encounter to date with Europa. Funding to continue mission operations and data analysis activities is included.

**Life and Microgravity Sciences and Applications**

The Life and Microgravity Sciences and Applications program uses the space environment to understand the response of biological and materials systems to weightlessness. Six Shuttle missions involving materials and life sciences experiments were conducted in 1996, includeing two Spacelab missions and three NASA/MIR missions. In addition to conducting basic and applied research, these missions have provided the opportunity to refine the definition, design, and development of experiment hardware planned for use on the International Space Station. These research activities will continue during FY 1997 as U.S. astronauts continue their visits to the Mir. Three joint Russian/U.S. flights were conducted in FY 1996, and three flights are planned for FY 1997. In addition to the Mir missions, the Materials Sciences Laboratory (MSL-1) mission is planned. In 1998, the NASA/NIH Neurolab mission is planned, which will continue the agency's efforts to expand its collaborative activities with the National Institutes of Health and other federal agencies to maximize the return on science investments. Funding for development of the International Space Station payloads is included in the Human Space Flight appropriation beginning in FY 1998.

**Mission to Planet Earth**

The Mission to Planet Earth (MTPE)program seeks to improve the scientific understanding of the Earth system, including the mechanisms that drive the climate and ecology of Earth, and how human activity is affecting the environment. NASA's base program combines ground-based measurements , laboratory studies, data analysis and model development with a progressive series of satellite missions to study cloud climatology, Earth radiation budget, ozone levels, atmospheric chemistry, changes in land cover and ocean circulation. This is just a first step. The capability to model and predict the consequences of global change is the ultimate objective.

The ongoing Mission to Planet Earth program is making critical near-term contributions to understanding the Earth as an integrated system as well as environmental issues, such as global warming and ozone depletion. Data from satellites and instruments in orbit, such as Total Ozone Mapping Spectrometer (TOMS),the NASA Scatterometer on the Japanese Advanced Earth Observing System, the Upper Atmospheric Research Satellite (UARS) and Ocean Topography Experiment (TOPEX)/Poseidon, and the Earth Radiation Budget Experiment (ERBE)are being used in multidisciplinary studies focused on understanding various aspects of the global environment.

The Earth Observing System (EOS) is a key element in the Administration's U.S. Global Change Research Program, and NASA's major contribution to this effort. The EOS is a series of spacecrafts designed to provide long-term data sets for use in modeling and understanding global processes. The Earth Probes provide data in specialized areas, such as tropical rainfall, ocean wind speed and direction, and global ozone concentrations. The EOS Data Information System (EOSDIS)will provide the processing, storage, and distribution of the EOS science data and resulting scientific products. Funding for the continued development of the Landsat-7 spacecraft, instruments and ground system is included. Landsat-7 is scheduled to launch in 1998. After launch and check out, the National Oceanic and Atmospheric Administration (NOAA)will be responsible for Landsat-7 operations.

Funding requested for FY 1997 and FY 1998 supports the continued development of the EOS program, including a robust science program. The first EOS satellites, Landsat-7 and EOS *AM*-1, will be launched in 1998. Preceeding launch of the EOS satellites, a number of individual satellite and Shuttle based missions are helping to reveal basic processes. Complementing EOS will be a series of small, rapid development Earth System Science Pathfinders missions, and an aggressive technology development program to provide for the infusion of innovative new technologies into the second and third series of EOS measurements. Funding is also included to initiate a data purchase program designed to acquire from private sources data sets that are necessary to accomplish broad research goals of Earth system science. Funding is also included to support three initiatives which will further contribute to a robust science program and to technology infusion. These initiatives include: an uncrewed aerial vehicle-based scientific research program to make detailed temporal changes by staying over a target area for extended periods of time; an instrument incubator for enabling rapid deployment of new, less costly and less resource-intensive scientific instruments: and, an initiative for concept/technology studies of the application of the latest technology to the development of small, compact, geostationary satellites to reduce operations costs.

## Aeronautics and Space Transportation Technology

The Aeronautics and Space Transportation Technology program provides high payoff, critical technologies with effective transfer of design tools and technology products to industry and government. A new Headquarters program office was established in FY 1997 to reflect the incorporation of the Advanced Space Transportation and Commercial Programs activities into the Office of Aeronautics, following the dissolution of the Office of Space Access and Technology in 1996.

The Aeronautics program provides a broad foundation of advanced technology to strengthen the United States' leadership in aviation, an industry which plays a vital role in the economic strength, transportation infrastructure and national defense of the United States. The NASA Aeronautics program provides the nation with leadership in high payoff critical technologies which are transferred to industry, the Department of Defense, and the Federal Aviation Administration for application to safe, superior and

environmentally compatible U.S. civil and military aircraft, and for a safe and efficient National Aviation System. NASA's unique research capabilities contribute to the strengthening of America's aviation industry in many ways, and the FY 1998 program continues important investments required to pursue the high leverage technologies required to support both the subsonic and high-speed civil transport economic viability. The Advanced Subsonic Transport (AST)program continues to make substantial progress in the development of high-risk, high-payoff technologies for a new generation of environmentally compatible, economic subsonic aircraft and a safe, highly productive global air transportation system. The AST program is refocused to emphasize technologies which will signficantly enhance the safety of the aviation system, improve the environment through noise and emissions reductions, and increase the capacity for a highly productive global air transportation system. Funding is included to continue development of high payoff technologies enabling a safe, highly productive global air transportation system with reduced environmental impact. Phase 11 of the High Speed Research program, begun in FY 1994, is directed at developing and verifying. in cooperation with U.S. industry, the high leverage technologies essential for economic viability in addition to environmental compatibility. A preliminary conceptual definition of a supersonic transport technology configuration was selected and efforts to develop these technologies continue. NASA is an active participant in the High Performance Computing and Communications (HPCC)program, and has pioneered the application of design and simulation software on parallel machines and developed the most widely accepted performance evaluation/tuning software for applications on parallel machines. Research activities conducted within the Research and Technology Base provide a foundation for longer-term technology development for application by industry and are organized around customer-driven discipline areas. As part of the HPCC program, the President's FY 1998 budget proposes $100 million each year for the next three years to support a new Next Generation Internet initiative whose goal is to develop a research network capable of achieving speeds of 100 to 1,000 times faster than today's Internet and large gains in the quality of service. This initiative will involve several Federal agencies including Defense, National Science Foundation, Energy, Commerce, and NASA. NASA's contribution to this effort is $10 million.

The Space Transportation Technology program leads NASA's efforts to develop advanced space technologies critical to the economic, scientific, and technological competitiveness of the U.S. New technologies critical to revitalizing access to space have been targeted for their potential to reduce launch costs dramatically over the next decade, and increase safety and the reliability of current and future generation launch vehicles. In 1996, the Reuseable Launch Vehicle program continued to pursue technology development and concept definition activities in support of next generation reusable systems, focusing on the X-34 and X-33 flight demonstrators. In 1996, the Administration approved the decision to proceed with Phase II of the X-33 program. Funding is included to continue technology development in preparation for flight of the technology demonstrators. Funding is also included to continue the Advanced Space Transportation Program (ASTP),to develop key technologies to dramatically reduce space transportation costs across the mission spectrum. The ASTP program will focus on technological advances with the potential of reducing launch costs beyond RLV goals, as well as supporting technology development required to support NASA strategic needs not addressed by RLV.

Funding for the Commercial Technology Program is continued, to support development of commercial partnerships with industry. In FY 1997 and FY 1998, emphasis will be on increasing commercial partnerships with industry and continued refinement of a technology and partnership database.

### Academic Programs

Science and mathematics achievement is an integral element of the National Education Goals, and NASA's efforts in the education arena strongly support making U.S. students first in the world in science and mathematics achievement by the year 2000. NASA's programs at the pre-college, college and graduate levels use NASA's unique mission and results to capture and channel student interest in science, mathematics and technology, as well as enhance teacher and faculty knowledge and skills related to these subjects. At the undergraduate and graduate level, programs are geared to providing opportunities for students and faculty to participate in NASA-sponsored research activities at NASA field centers.

NASA has made a commitment to playing a leadership role in strengthening the capabilities of minority universities and to increasing opportunities for students at Historically Black Colleges and Universities and Other Minority Universities, primarily Hispanic-serving institutions and Tribal Colleges, to participate in and benefit from NASA's research and education programs. The FY 1998 budget request for the Minority University Research program continues this commitment through funding for initiatives which are underway.

### Mission Communication Services

Support which is most directly related to NASA's science and aeronautics programs, including ground network support, mission planning for robotics spacecraft programs, suborbital mission support, support to aeronautics test programs, and technology development activities to improve the state of space communications technology, is included in the Science Aeronautics and Technology appropriation.

## MISSION SUPPORT

### Safety, Reliability, Maintainability and Quality Assurance

NASA is committed to providing leadership in quality management of science and engineering programs. The Office of Safety and Mission Assurance (OSMA) is responsible for the development and implementation of risk management practices and Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) practices into all NASA activities. The funding requested will continue a wide range of activities underway through which SRM&QA practices are integrated into the earliest phases of development for space and aeronautics programs. The Office of the Chief Engineer provides a focus for NASA's engineering discipline, oversees applications, and improves NASA's practices and capabilities through targeted initiatives in the Engineering programmatic area.

### Space Communications Services

Funding for the operation, sustainment, and replenishment of NASA's Space Network is in NASA's Mission Support appropriation. This program supports the operation of the Tracking and Data Relay Satellite (TDRS) System, the ground terminals at White

Sands, New Mexico, and the NASA Control Center at the Goddard Space Flight Center. Funds for services provided to non-science users of the TDRSS are included under this program. The NASA Communications (NASCOM) system and the Program Support Communications Network (PSCN) are also funded by this appropriation. Planning is underway to consolidate and streamline major support contract services in order to optimize space operations. In FY 1996, as an interim measure, a voluntary contractor partnership between the major incumbents, AlliedSignal Technical Services Corporation and Computer Sciences Corporation was formed. A new contract is required in FY 1998. At that time, transition to a performance-based space operations contract, or possibly, a privatized or commercialized operation will be decided. The FY 1998 budget proposes multi-year appropriations for development and launch of three Tracking and Data Relay satellite (TDRS) replenishment spacecraft. The multi-year funding will support NASA's plans for the TDRS fixed price spacecraft contract with industry.

**Research and Program Management**

The NASA workforce is the foundation underpinning the successful achievement of NASA's goals. Funding for the salaries, travel support and other personnel expenses for the entire NASA workforce is included. Funding for support activities to the NASA workforce and physical plant is also included in Research and Program Management.

NASA's workforce in the year 2000 will be focused on the crucial research and development that will keep this country even with the incredible pace at which the global economy is changing. The largest segment of savings resulting from the Zero Base Review is achieved from reductions in planned levels of civil service staffing and support. Current planning supports a civil service workforce of around 18,000 by FY 1999. This workforce will be technically outstanding to meet the challenges of NASA's diverse and highly technical programs, and will be engaged in activities which keep NASA at the forefront of cutting edge technology development.

**Construction of Facilities**

Funding is included for discrete projects to repair and modernize the basic infrastructure and institutional facilities, the minor repair, rehabilitation and modification of existing facilities, minor new construction projects, environmental compliance and restoration activities, the design of facilities projects, and the advanced planning related to future facilities needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1998 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| | (Thousands of Dollars) | | |
| **HUMAN SPACE FLIGHT** | 5,710.4 | 5,674.8 | 5,326.5 |
| SPACE STATION | 2,143.6 | 2,148.6 | 2,121.3 |
| US/RUSSIAN COOPERATION | 100.0 | 100.0 | -- |
| SPACE SHUTTLE | 3,143.8 | 3,150.9 | 2,977.8 |
| PAYLOAD AND UTILIZATION OPERATIONS | 323.0 | 275.3 | 227.4 |
| **SCIENCE, AERONAUTICS AND TECHNOLOGY** | 5,670.4 | 5,453.1 | 5,642.0 |
| SPACE SCIENCE | 2,175.9 | 1,969.3 | 2,043.8 |
| LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS | 304.2 | 243.7 | 214.2 |
| MISSION TO PLANET EARTH | 1,360.8 | 1,361.6 | 1,417.3 |
| AERONAUTICS AND SPACE TRANSPOWATION TECHNOLOGY | 1,270.1 | 1,339.5 | 1,469.5 |
| MISSION COMMUNICATION SERVICES | 449.5 | 418.6 | 400.8 |
| ACADEMIC PROGRAMS | 109.9 | 120.4 | 96.4 |
| **MISSION SUPPORT** | 2,487.3 | 2,564.3 | 2,513.2 |
| SAFETY, RELIABILITY AND QUALITY ASSURANCE | 39.0 | 38.8 | 37.8 |
| SPACE COMMUNICATION SERVICES | 255.4 | 277.7 | 245.7 |
| RESEARCH AND PROGRAM MANAGEMENT | 2,047.9 | 2,092.5 | 2,070.3 |
| CONSTRUCTION OF FACILITIES | 145.0 | 155.3 | 159.4 |
| **INSPECTOR GENERAL** | 15.9 | 17.0 | 18.3 |
| **TOTAL BUDGET AUTHORITY** | 13,884.0 | 13,709.2 | 13,500.0 |
| **TOTAL OUTLAYS** | 13,881.0 | 13,697.0 | 13,594.0 |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1998 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS
(IN MILLIONS OF REAL YEAR DOLLARS)

| | TOTAL | Human Space Flight | Science, Aero & Technology | Mission Support | Inspector General |
|---|---|---|---|---|---|
| **FISCAL YEAR 1996** | **13,884.6** | **5,456.6** | **5,928.9** | **2,483.1** | **16.0** |
| FY 1996 OMNIBUS APPROPRIATIONS ACT (P.L. 104-134) APPROPRIATIONS TRANSFER AUTHORITY | **0.0** | *50.0* | -50.0 | | |
| LAPSE OF FY 1996 UNOBLIGATED FUNDS | **-0.6** | | | **-0.5** | -0.1 |
| **TOTAL FY 1996 BUDGET PLAN** | **13,884.0** | **5,506.6** | **5,878.9** | **2,482.6** | **15.9** |
| **FISCAL YEAR 1997** | | | | | |
| VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 1997 (P.L. 104-204) | **13,704.2** | **5,362.9** | **5,762.1** | **2,562.2** | **17.0** |
| OMNIBUS CONSOLIDATED APPROPRIATIONS ACT (P.L. 104-208) | **5.0** | | ***5.0*** | | |
| VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 1997 (P.L. 104-204) APPROPRIATIONS TRANSFER AUTHORITY | **0.0** | 177.0 | -177.0 | | |
| **TOTAL FY 1997 BUDGET PLAN** | **13,709.2** | **5,539.9** | **5,590.1** | **2,562.2** | **17.0** |

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## FISCAL YEAR 1998 ESTIMATES

## DISTRIBUTION OF PROGRAM AMOUNT BY INSTALLATION
## (Thousands of Dollars)

| | Total | | | Human Space Flight | | | Science, Aeronautics and Technology | | | Mission Support | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1996 | 1997 | 1998 | 1996 | 1997 | 1998 | 1996 | 1997 | 1998 |
| Johnson Space Center | 3.548.062 | 3,535.168 | 3,380,330 | 3.073.329 | 3.094.300 | 2,966,000 | 103.869 | 75.138 | 64.030 | 370,764 | 365.730 | 350.300 |
| Kennedy Space Center | 1,214,942 | 1,189,989 | 1,176,330 | 935.249 | 921.100 | 904.300 | 28.334 | 29.439 | 31,430 | 251.359 | 239.450 | 240.600 |
| Marshall Space Flight Center | 2.465.676 | 2,565,991 | 2.343.615 | 1,502,684 | 1,519,200 | 1.306.900 | 609,852 | 677.321 | 638.015 | 353,140 | 369.470 | 398.700 |
| Stennis Space Center | 161.662 | 170.064 | 119.100 | 53.300 | 42.200 | 35.300 | 69.067 | 79.914 | 33.000 | 39.295 | 47.950 | 50.800 |
| Ames Research Center | 590.740 | 522.871 | 563,649 | 26.296 | 19.900 | 27.300 | 390.835 | 323.501' | 355.049 | 173.609 | 179.470 | 181.300 |
| Dryden Flight Research Center | 136.164 | 168.379 | 181.874 | 5.600 | 5.400 | 5.900 | 86,697 | 101.449 | 114.074 | 43.867 | 61.530 | 61.900 |
| Langley Research Center | 607.805 | 636,827 | 648.320 | 5.167 | 9.300 | 4.900 | 390.138 | 411.477 | 419.320 | 212.500 | 216.050 | 224.100 |
| Lewis Research Center | 694.425 | 621.540 | 671.501 | 44.136 | 18.100 | 26,600 | 428.097 | 368.220 | 383.901 | 222.192 | 235.220 | 261,000 |
| Goddard Space Flight Center | 2.511.355 | 2,723,809 | 2.763.979 | 10.365 | 7.400 | 7.600 | 1.975.293 | 2.162.869 | 2.291,979 | 525.697 | 553.540 | 464,400 |
| Jet Propulsion Laboratory | 1,069,945 | 1.002.499 | 1,045,110 | 2.600 | 200 | 2.800 | 1,037,248 | 970.559 | 1.014.710 | 30.097 | 31.740 | 27.600 |
| Headquarters | 848.893 | 531.163 | 560.192 | 51,674 | 37.700 | 38.900 | 550.870 | 253.213 | 296.492 | 246.349 | 240.250 | 224.800 |
| Undistributed: | | | | | | | | | | | | |
| Construction of Facilities: | | | | | | | | | | | | |
| Various locations | 18.470 | 23.900 | 27.700 | | | | | | | 18.470 | 23.900 | 27.700 |
| Inspector General | 15.863 | 17,000 | 18.300 | | | | | | | | | |
| TOTAL NASA | 13.884.002 | 13,709,200 | 13,500,000 | 5,710,400 | 5,674,800 | 5,326,500 | 5,670,400 | 5.453.100 | 5,642,000 | 2,487,339 | 2,564,300 | 2,513,200 |

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## PROPOSED APPROPRIATION LANGUAGE

ADMINISTRATIVE PROVISIONS

[INCLUDING TRANSFER OF FUNDS]

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 [(1)] any activity has been initiated by the incurrence of obligations for construction of facilities as authorized by law, [or *(2)* amounts are provided for full-funding for the Tracking and Data Relay Satellite (TDRS)replenishment program.] 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 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, [1999] *2000.*

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, [1997] *1998* and may be used to enter into contracts for training. investigations. cost associated with personnel relocation, and for other services, to be provided during the next fiscal year.

[Upon the detemiination by the Administrator that such action is necessary, the Administrator may, with the approval of the Office of Management and Budget, transfer not to exceed $177,000,000 of funds made available in this Act to the National Aeronautics and Space Administration for the International Space Station between "Science, aeronautics and technology" and 'Human space flight". to be merged with and to be available for the same purposes, and for the same time period. as the appropriation to which transferred; Provided. That such authority may not be used unless for higher priority items than those for which originally appropriated; *Provided further,* That the Administrator of the National Aeronautics and Space Administration shall notify the Congress promptly of all transfers made pursuant to this authority.] ***(Departments of Veterans Affairs and* Housing *and Urban Development, and Independent Agencies Appropriations Act, 1997.)***

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

### FISCAL YEAR 1998 ESTIMATES
### (IN MILLIONS OF REAL YEAR DOLLARS)

The FY 1998 multi-year budget estimate is submitted in accordance with the NASA FY 1989 Authorization Law (P.L. 100-685).

| | 1996 PAST YEAR | 1997 CURRENT YEAR | 1998 BUDGET YEAR | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|
| **HUMAN SPACE FLIGHT** | **5,710.4** | **5,674.8** | **5,326.5** | **5,306.3** | **5,077.0** | **4,831.5** | **4,675.3** |
| SPACE STATION | 2,143.6 | 2,148.6 | 2,121.3 | 2,109.2 | 1,914.6 | 1,596.8 | 1,515.8 |
| US/RUSSIAN COOPERATIVE PROGRAM | 100.0 | 100.0 | | | | | |
| SPACE SHUTTLE | 3,143.8 | 3,150.9 | 2,977.8 | 3,018.5 | 2,978.6 | 3,053.6 | 2,977.6 |
| PAYLOAD AND UTILIZATION OPERATIONS | 323.0 | 275.3 | 227.4 | 178.6 | 183.8 | 181.1 | 181.9 |
| **SCIENCE, AERONAUTICS AND TECHNOLOGY** | **5,670.4** | **5,453.1** | **5,642.0** | **5,626.2** | **5,750.1** | **5,951.2** | **5,989.4** |
| SPACE SCIENCE | 2,175.9 | 1,969.3 | 2,043.8 | 2,025.4 | 2,155.9 | 2,219.9 | 2,219.9 |
| LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS | 304.2 | 243.7 | 214.2 | 249.8 | 256.9 | 266.3 | 264.1 |
| MISSION TO PLANET EARTH | 1,360.8 | 1,361.6 | 1,417.3 | 1,446.3 | 1,575.7 | 1,543.3 | 1,492.0 |
| AERONAUTICS & SPACE TRANSPORTATION TECHNOLOGY | 1,270.1 | 1,339.5 | 1,469.5 | 1,366.4 | 1,147.0 | 1,173.4 | 1,194.3 |
| MISSION COMMUNICATION SERVICES | 449.5 | 418.6 | 400.8 | 436.1 | 438.3 | 437.5 | 432.9 |
| ACADEMIC PROGRAMS | 109.9 | 120.4 | 96.4 | 102.2 | 102.2 | 102.2 | 102.2 |
| FUTURE PLANNING | | | | | 74.1 | 208.6 | 284.0 |
| **MISSION SUPPORT** | **2,487.3** | **2,564.3** | **2,513.2** | **2,458.9** | **2,354.0** | **2,398.3** | **2,516.0** |
| SAFETY, RELIABILITY AND QUALITY ASSURANCE | 39.0 | 38.8 | 37.8 | 43.0 | 42.6 | 42.4 | 42.2 |
| SPACE COMMUNICATION SERVICES | 255.4 | 277.7 | 245.7 | 204.4 | 139.5 | 147.5 | 175.5 |
| RESEARCH AND PROGRAM MANAGEMENT | 2,047.9 | 2,092.5 | 2,070.3 | 2,022.6 | 1,968.1 | 2,011.3 | 2,101.2 |
| CONSTRUCTION OF FACILITIES | 145.0 | 155.3 | 159.4 | 188.9 | 203.8 | 197.1 | 197.1 |
| **INSPECTOR GENERAL** | **15.9** | **17.0** | **18.3** | **18.6** | **18.9** | **19.0** | **19.3** |
| **TOTAL** | **13,884.0** | **13,709.2** | **13,500.0** | **13,410.0** | **13,200.0** | **13,200.0** | **13,200.0** |

FY 1997 Changes

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**CHANGES FROM FY 1997 BUDGET ESTIMATE TO FY 1997 CURRENT ESTIMATE**
(Dollars in Millions)

## HUMAN SPACE FLIGHT

The funding level for the Human Space Flight appropriation of $5,539.9 milllion reflects an increase of $177.0 million. The distribution of this increase, and other proposed funding reallocations, are included below.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Space station** | **1,802.0** | | **177.0** | **0.0** | **1979.0** |
| Development | 1,513.2 | | 177.0 | 76.1 | 1766.3 |
| Construction of facilities | | | | | |
| Utilization support | 72.1 | | | -37.0 | 35.1 |
| Operations | 216.7 | | | -39.1 | 177.6 |

## CHANGE FROM FY 1997 BUDGET ESTIMATE

This total increase of $177.0 million reflects the management decision to increase the level of funding available for potential changes and contingencies to mitigate the risk of delay during this critical period of activity. The Space Station program remains on a challenging schedule for the First Element Launch (FEL) in late 1997 and the management team continues to closely monitor activities. The program continues to make excellent progress in meeting its milestones in support of FEL. NASA continues to be concerned that the level of program reserves be maintained at as high a level as possible to address technical issues that are expected to inevitably occur during this peak period of Space Station engineering and development.

The increase of $177.0 million reflected in the FY 1997 Current Estimate reflects the transfer of funds from the Science, Aeronautics, and Technology account, as provided in P.L. 104-204. This additional funding is needed to maximize needed flexibility within the $2.149 billion appropriated for FY 1997 for Station Development. To accomplish this transfer, funding for Life and Microgravity Sciences support, including funds previously included in the Space Access and Technology Program for Space Station Uilization, is reduced $177.0 million, from $299.4 million to $122.4 million. These funds are available as a result of a major review of the Space Station Research Program. This review recommended that research facilities' development schedules be adjusted to be more closely aligned with the availability of research resources on the Space Station during the assembly phase. In

addition, in 1996, key procurement activities were suspended during the conduct of a major Space Station facilities review. This procurement freeze resulted in the buildup of unobligated funds. Currently, NASA is reviewing every facility, payload, and user operation against the NASA research objectives for the Space Station to ensure that the maximum strategic and scientific return is achieved. We are replanning our Space Station science research facility activity to match the on-orbit resources available during the Space Station assembly period in a manner which will ensure that most of those facilities are available on-orbit by Station Assembly Complete in 2002. It is anticipated that this replanning effort will be complete in March 1997.

Funding for elements of the Space Station program are also reallocated to Station Development. Funding for Utilization Support is reduced $37.0 million and funding for Operations is reduced $39.1 million. These reductions are accommodated by deferring planned activities and reallocating reserves to Development. These reallocations reflect updated estimates to the funding distribution included in NASA's initial 1997 Operating Plan.

NASA also remains concerned regarding the lack of Russian government funding for its contributions to the ISS program and the potential for schedule impacts resulting from such a lack of funding. We are continuing to work closely with the Russian Space Agency to mitigate any potential delays. In order to reduce reliance on the delivery schedule of Russian flight elements and enhance early launch robustmess of the ISS, NASA is actively considering ways to increase Station assembly sequence flexibility. Contingency efforts are continuing to provide early U.S. control and reboost capability to ensure early launch integrity. This capability is highly desirable, even if the Russian elements are delivered on schedule, since that capability provides redundancy for critical-path elements throughout Space Station assembly and operations. Preliminary estimates for providing possible added or modified hardware (e.g. interim control module and long-lead items for propulsion module) to protect the early Space Station assembly integrity indicate that implementing these contingencies will reduce significantly available program reserves. NASA will implement such contingencies for the ISS as required, although other offsetting actions could be required to ensure adhering to NASA's commitment to the annual $2.1 billion funding limitation. These actions do not threaten the total $17.4 billion development estimate.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **U.S/Russian cooperation** | **138.2** | | | | **138.2** |

There is no change to the budget request.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Space shuttle** | **3150.9** | | | | **3150.9** |
| Shuttle Operations | 2514.9 | | | | 2514.9 |
| Orbiter and integration | 516.6 | | | | 516.6 |
| Propulsion | 1098.7 | | | | 1098.7 |
| Mission and Launch Operations | 899.6 | | | | 899.6 |
| Safety and performance upgrades | 636.0 | | | | 636.0 |
| Orbiter Improvements | 169.9 | | | | 169.9 |
| Propulsion Upgrades | 342.8 | | | | 342.8 |
| Flight operations and launch site equipement | 115.0 | | | | 115.0 |
| Construction of facilities | 8.3 | | | | 8.3 |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

There is no reduction from the requested level. NASA's first priority for the Space Shuttle program remains unchanged -- safety of flight. Award of the Shuttle Operations Consolidated Contract to United Space Alliance was accomplished on October 1, 1996. Transition activities will continue over the next 2 years. NASA's insistence on improving flight safety in the Space Shuttle program has resulted in the identification of $70.0 million within the Safety and Performance Upgrades program to implement additional upgrades to the Space Shuttle. The objective is to increase reliability and maintainability; any benefits in the form of reduced program costs will be a fallout of our emphasis on reliability and maintainability. The upgrades will be selected on the basis of improving Space Shuttle safety and upgrading system performance and efficiency. The funds are available, due to the lower than planned obligation and cost rates experienced in the Shuttle program during FY 1996.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Payload and utilization operations** | **271.8** | | | **0.0** | **271.8** |
| Spacelab | 62.4 | | | -12.1 | 50.3 |
| Payload Processing and Support | 42.7 | | | -1.0 | 41.7 |
| Advanced projects | 15.2 | | | 16.0 | 31.2 |
| Engineering and technical base | 151.5 | | | -2.9 | 148.6 |

## CHANGE FROM FY 1997 BUDGET ESTIMATE

Total funding for Payload and Utilization Operations is unchanged. However, funding is reallocated within Payload and Utilization Operations to support the continued development and flight testing of critical technologies for the X-38 experimental vehicle project. $16 million is reallocated to the X-38 effort, bringing the FY 1997 total to $21 million. The funds are available to reallocate for this purpose, due to better-than-anticipated cost performance in FY 1996 in the Payload and Utilization Operations program. These funds will be used to continue advanced technology development tasks focused on the reduction of development and operating costs for future human space vehicles, including the Crew Return Vehicle. This funding will enable space qualification of advanced technologies such as electromechanical actuators, laser-initiated pyrotechnics, damage-resistant thermal protection systems, low-cost rapid production composite skin panels, avionics hardware, and rule-based expert system software. NASA's objective is to integrate these technologies into an initial atmospheric drop demonstration vehicle to be flight tested within the nex year.

## SCIENCE, AERONAUTICS AND TECHNOLOGY

The funding level in FY 1997 for the Science, Aeronautics and Technology appropriation of $5,590.1 million reflects a general reduction of $95.0 million as directed in House Report 104-812, and the transfer of $177.0 million to the Human Space Flight account as provided for in P.L. 104-204. The distribution of the general reduction is Space Science (-$20.0 million) and Mission to Planet Earth (-$75.0 million). The distribution of funding for activities previously included in the Space Access and Technology Program is also included below. In July 1996, each of the Enterprise Associate Administrators was given responsibility for fully integrating the science goals and technology requirements of their programs. Technology development activities previously conducted under the management of the Associate Administrator for Space Access and Technology have been reassigned to the direct management of the relevant Enterprise Associate Administrators, and implementation plans are in development. The realignment of funding to match the movement of program management responsibility, the impact of the general reduction, and other proposed funding reallocations, are included below.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Space science** | **1857.3** | **133.6** | | **-20.0** | **1970.9** |
| Advanced x-ray astrophysics facility | 178.6 | | | | 178.6 |
| Relativity mission development | 59.6 | | | | 59.6 |
| Cassini | 106.7 | | | -17.1 | 89.6 |
| TIMED | | | | 18.2 | 18.2 |
| Payload and instrument development | 16.9 | | | | 16.9 |
| Explorers | 135.0 | | | -10.0 | 125.0 |
| Discovery | 74.8 | | | 2.0 | 76.8 |
| Mars Surveyor | 90.0 | | | | 90.0 |
| New Millennium | 21.5 | | | 27.1 | 48.6 |
| Spacecraft and Remote Sensing | | 133.6 | | | 133.6 |
| Mission operations and data analysis | 592.4 | | | -9.1 | 583.3 |
| Supporting Research and technology | 259.2 | | | -13.2 | 246.0 |
| Suborbital program | 69.1 | | | -5.0 | 64.1 |
| Launch services | 253.5 | | | -12.9 | 240.6 |

### CHANGE FROM FY 1997 BUDGET ESTIMATE

Funding for Space Science totals $1970.9 million, a net increase of $113.6 million from the requested level. This net increase reflects reallocation of $133.6 million from Space Access and Technology for Spacecraft and Remote Sensing activities, offset by a reduction of $20 million as part of the $95 million general appropriations reduction directed by Congress. Along with the

allocation of $20 million of the general reduction, this plan for Space Science includes an increase of $10 million for the development of the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) mission, as directed in House Report 104-812. Both the general reduction for Spce Science and increase in funding for TIMED are accommodated by taking advantage of uncosted balances in excess of program requirements in Launch Services, Explorers, NEAR Operations, and Stratospheric Observatory for Infrared Astronomy. The total available for obligation for TIMED in FY 1997 is $20 million: of this amount, $1.8 million is for Phase B activities, and $18.2 million is for development. Development activities on this mission are scheduled to begin in spring 1997, assuming that NASA's Program Management Council determines that the definition is sufficiently mature and that development estimates are sustainable. A decision to proceed with development of TIMED in spring 1997 would support a launch date of January 2000.

Funding for the Discovery program is increased $2.0 million, to $76.8 million, to support Phase A study efforts for the next Discovery mission. Selection of missions for Phase A is scheduled for Spring 1997. Funding for the Mars Surveyor program is unchanged: however, funding for the Mars Surveyor '98 Orbiter/Lander is increased $9.4 million. Fabrication of the Orbiter/Lander spacecraft is underway, and the increase to program reserves will reduce the development schedule risk with no increase in total project cost. Funding originally budgeted for the Mars Global Surveyor in FY 1997 can be made available for this purpose, due to excellent cost performance in FY 1996 by the Jet Propulsion Laboratory.

Funding for the New Millennium program is increased $27.1 million. The better-than-anticipated cost performance in FY 1996 for science programs and a close scruting of FY 1997 funding requirements for launch vehicles enable this reallocation. The Deep Space-1 spacecraft funding is increased $6.9 million, reflecting a rebalancing of funding between the spacecraft and launch vehicle budgets, with no increase in total project cost. Funding for Technology Development is increased $17.2 million to support additional technology efforts, including integrated technology development teams: some of the reallocated funds will enable the project to initiate funding for a Delta launch vehicle. Using a Delta instead of a Taurus launch vehicle will enable a more ambitious demonstration mission. The final increment of this increase, $3.0 million, will support a new technology thrust in outer planets technology, focusing on power systems technology. The better than anticipated cost performance occurred in the Cassini program, allowing a reallocation of $17.1 million of available reserves, and in Mission Operations and Data Analysis/NEAR Operations, allowing a reallocation of $3.1 million. The remainder of $6.9 million results from replanning of the Launch Services budget

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP RANSFER | OTHER CHA | CURRENT ST |
| **Life and microgravity sciences and applications** | **498.5** | **44.6** | **-177.0** | **0.0** | **366.1** |
| Life Sciences | 106.2 | | -12.1 | 15.6 | 109.7 |
| Research and analysis | 49.8 | | | 8.2 | 58.0 |
| Flight program.. | 56.4 | | -12.1 | 7.4 | 51.7 |
| Microgravity research | 144.3 | | -13.4 | | 130.9 |
| Research and analysis | 33.6 | | | -1.7 | 31.9 |
| Flight program.. | 110.7 | | -13.4 | 1.7 | 99.0 |
| Aerospace medicine | 6.5 | | | -2.2 | 4.3 |
| Shuttle/spacelab payload mission management and integration | 54.4 | | -4.2 | -13.4 | 36.8 |
| Space station payload facilities | 187.1 | | -120.7 | | 66.4 |
| Space Product Development | | 44.6 | -26.6 | | 18.0 |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

Funding for Life and Microgravity Sciences is $366.1 million, a net reduction of $132.4 million from the request. This net reduction reflects the redistribution of $44.6 million from Space Access and Technology for Space Product Development and the Space Station Utilization program and the transfer of $177 million to the Human Space Flight appropriation. The total includes $4.0 million for cardiac imagery activities at the Cleveland Clinic and $4.0 million for space radiation health activities, as directed in House Report 104-812. A NASA site visit to the Cleveland Clinic occurred in late November 1996, and further definition of these activities is underway. The augmentation in funding for the Space Radiation Health program will continue ongoing research to establish the scientific basis for protecting humans engaged in the development and exploration of space from radiation hazards. In addition, funding for Life Sciences is increased $15.6 million to support additional principal investiagor activities in the areas of Advanced Life Support, Countermeasures, and Gravitational Biology, and for Advanced Human Support technology activities to enhance human performance in space. Funding increases are included for additional science and engineering, support for the Neurolab Spacelab mission, scheduled for FY 1998, and to cover flight program infrastructure requirements, such as data archiving, animal care, and program support costs, which are now included in Flight Programs as a result of the Space Station Research program restructuring activity. These increases are partially offset by savings achieved in the Space Transportation

System/Spacelab Mission Management and Integration program based on the Zero-Base review, the Spacelab Reengineering process, and reduced estimates of Spacelab termination costs.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Mission to planet Earth** | **1,402.1** | **51.5** | | **-83.0** | **1,370.6** |
| Earth observing system | 585.7 | 30.5 | | -20.5 | 595.7 |
| Earth observing system data information system | 261.1 | | | -6.5 | 254.6 |
| Earth probes | 47.1 | 5.0 | | 5.1 | 57.2 |
| Applied research and data analysis | 379.1 | 16.0 | | -21.7 | 373.4 |
| Launch services | 124.1 | | | -39.4 | 84.7 |
| GLOBE | 5.0 | | | | 5.0 |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

Funding for Mission to Planet Earth (MTPE)totals $1,370.6 million, a net reduction of $31.5 million from the request, which is made up of a reduction of $75 million as part **of** the $95 million general appropriations reduction directed by Congress and reallocation of $8 million to Academic Programs, offset by a reallocation of $51.5 million from the Space Access and Technology program. The reductions have been achieved by applying funds available from a close review of uncosted carryovers and new obligational authority against projected cost requirements in FY 1997.

The MTPE plan includes $50 million, as requested, for a commercial Data Purchase to support critical MTPE science requirements. A formal solicitation for this initiative will be released early next year with the Commercial Remote Sensing program at the Stennis Space Center (SSC)playing a major role in its implementation. The commercial data purchase highlights NASA's plan to develop SSC's role and capabilities as NASA's Lead Center and focal point for commercial remote sensing. *Also* included in the total for MTPE is an increase of $12 million for the "lightSAR" program, consistent with direction included in House Report 104-812. House Report 104-812 stipulates that NASA's FY 1998 budget request should include additional funding to accomplish this program. The "LightSAR" program is currently one of the missions competing for possible funding under NASA's Earth Systems Science Pathfinder (ESSP)program and may also compete in the upcoming MTPE Data Purchase solicitation. Proposals for Windsat-type mmissions are also currently competing for funding within the ESSP solicitation. To address direction in House Report 104-812, the MTPE program includes a specific allocation of $5 million for a possible Windsat mission, pending the ESSP selection process. *Also* reflected in this Operating Plan is the reallocation of $8 million from MTPE to Academic Programs to

support development of a national center for science literacy, education, and technology at the American Museum of Natural History, as directed in House Report 104-812.

FY 1997 funding included within the Earth Observing System for Landsat-7 has been increased by a net of $2.3 million. NASA continues to monitor spacecraft assembly activities closely. This increase and the application of available reserves have enabled several specific program changes. First, funding for Landsat Development is augmented $5.6 million to accelerate completion of spacecraft assembly activities. The Lockheed Martin assembly plant in Valley Forge, Pennsylvania may close in late 1997, following shipment of the Landsat-7 spacecraft to the west coast launch site. This funding will be used to support additional workforce requirements to accomplish the remaining spacecraft activities on an accelerated schedule and to address any technical problems which might arise due to contractor workforce shortages resulting from plant closure activities. *Also* included in this Operating Plan is $4.2 million to continue operations preparation and start up activities for Landsat-7. The funding included in this plan will support operations preparation activities through January 1997. The National Oceanic and Atmospheric Administration (NOAA) will provide FY 1998 (and subsequent years) funding for operations, totaling $10.9 million in FY 1998.

Additional funding reallocations are reflected within the MTPE plan. Funding for the Earth Observing System has been increased by a net of $10 million, including the impacts of Congressional appropriations action, reallocation of funds from the Space Access and Technology Program, and actions to address contract funding issues. The AM series of spacecraft has been reduced by a net of $1.9 million. This reflects **a** series of changes and application of available funding. The MTPE plan includes reallocation of $6.0 million to support inclusion of X-band capability on the ***AM-*** 1 spacecraft. Also, $10.8 million has been reallocated to AM-1 to support additional spacecraft, instrument, transponder and integration requirements. These increases are offset by the application of available uncosted carryover and consolidation of program support. Funding for Special Spacecraft is increased $25.4 million, reflecting consolidation of common EOS program support activities in this budget line, a rephaisng of budget authority to ensure adequate carryover, and $2.8 million to support initiation of the Active Cavity Irradiance Monitor instrument in FY 1997. These increases are offset by reductions to the EOS-PM series as a result of the decision to delete the TDRS link in favor of direct X-band downlink (-$11.6 million), a slower start for the AM-2 spacecraft activities (-$12.1 million), which will not perturb the planned launch date, and application of available uncosted carryover funding across the EOS program. Funding for the Chemistry mission is reduced by a net of $14.1 million. Studies are underway to evaluate alternative ways to conduct this important mission, including flying the instruments separately on different spacecraft: however, no impact on the Chemsitry mission objectives is anticipated. Also included in $7 million to continue further development of high-payoff technologies, which will enable rapid deployment of new, less costly, and less resource-intensive scientific instruments.

The development of the EOS Data Information System (EOSDIS) ground system to support the Tropical Rainfall Measuring Mission (TRMM) and ***AM-*** 1 mission is behind schedule: however, the capability of EOSDIS to control spacecraft operations and capture the data is not in jeopardy. At this time, NASA is not proposing a reallocation of funds to address this issue, although it appears some reallocation within MTPE may be necessary during the fiscal year to ensure the timely capability to process the data. This Operating Plan reflects a reduction of $6.5 million for the EOSDIS, but this reduction derives simply from reallocation of funding for program support within the **EOS** program.

Within funding for Applied Research and Data, $1 million is included to begin concept definition studies for the Geostationary Advanced Technology Environmental Satellite and $2 million to begin instrument studies for an Uncrewed Aerial Vehicle science program. These increases are offset by reductions in available uncosted funding.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Space access and technology** | ***725.0*** | ***-725.0*** | | | **0.0** |
| Advanced space transportation | 324.7 | -324.7 | | | ***0.0*** |
| Spacecraft and remote sensing | 151.0 | -151.0 | | | ***0.0*** |
| Advanced smallsat technology | 30.0 | -30.0 | | | ***0.0*** |
| Space processing | 41.8 | -41.8 | | | ***0.0*** |
| Commercial technology programs | 24.2 | -24.2 | | | ***0.0*** |
| Technology transfer agents | 7.3 | -7.3 | | | ***0.0*** |
| Advanced concepts | 3.8 | -3.8 | | | ***0.0*** |
| Small business and innovative research program | 142.2 | -142.2 | | | ***0.0*** |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

Funding for activities previously budgeted in the Space Access and Technology program have been redistributed into the Space Science, Mission to Planet Earth, Aeronautics, and Life and Microgravity Sciences programs. This reallocation reflects the distribution of technology into the benefitting programs to achieve a closer alignment between the technology development activities and the programs which will be using the technology. Changes to budget estimates in FY 1997 for the redistributed activities are discussed in the relevant sections.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Aeronautics and Space Transportation Technology** | **857.8** | **487.3** | | **-1.6** | **1,343.5** |
| Aeronautics research and technology base ..... | 354.4 | | | 49.8 | 404.2 |
| Aeronautics focused technolow programs.. ..... | 503.4 | | | -63.4 | 440.0 |
| High performance computing & communications | 23.3 | | | | 23.3 |
| Numerical aerodynamic simulation.. ..... | 38.6 | | | -38.6 | 0.0 |
| High-speed research. ..... | 254.3 | | | -11.2 | 243.1 |
| Advanced subsonic technology ..... | 187.2 | | | -13.6 | 173.6 |
| Advanced Space Transportation Technology ..... | | 324.7 | | 12.0 | 336.7 |
| (Construction of Facilities) ..... | | (2.3) | | | (2.3) |
| Commercial Technolow ..... | | 158.6 | | | 158.6 |
| Advanced Concepts (managed by Chief Technologist) ..... | | 4.0 | | | 4.0 |

## CHANGE FROM FY 1997 BUDGET ESTIMATE

NASA's Aeronautics Program and elements of the Space Access and Technology Program have been redesignated as the Aeronautics and Space Transportation Technology Program, and are funded at a total of $1,343.5 million. This total represents a net increase of $485.7 million, as the result of the reallocation of $487.3 million from the Space Access and Technology program, offset by a reduction in the Advanced Subsonic Technology program and other adjustments. The previously designated Aeronautics Enterprise has been expanded to encompass the Commercial Development of Space and Advanced Space Transportation Technology activities formerly managed and funded by the Space Access and Technology Enterprise. There is obvious synergy between these programs, in their common focus on developing technologies that enable breakthroughs to enhance the global position of the United States industry, whether it be in aeronautics or space launch. The Aeronautics and Space Transportation Enterprise has been expanded to incorporate the Advanced Space Transportation Technology program into its strategic planning by establishing advances in access to space as one of the three "pillars" supporting its strategic vision.

Within funding included for the Advanced Space Transportation Technology program, $12.0 million is identified to augment funding for the Low Cost Booster Technology program, as directed in House Report 104-812. This additional funding will be used

for additional technology development solicited through a NASA research announcement. $2.3 million is included in Construction of Facilities for refurbishment of the **B-2** test stand at the Stennis Space Center to enable testing of the X-33 and flight engine development.

Within funding included for Aeronautics, $2.0 million has been realigned within the High Speed Research program, as directed in House Report 104-812. The increase of $49.8 million in the Research and Technology (R&T) Base reflects the reallocation of funding for the Environmental Research Aircraft and Sensor Technology (ERAST) project from High Speed Research to the R&T Base's Flight Research element, and the reallocation of funding for the Numerical Aerodynamic Simulator (NAS) to the R&T Base's Information Technology element. Funding for the Advanced Subsonic Technology program is reduced $13.6 million, reflecting termination of the fly-by-light/power-by-wire element of the program.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Mission Communication Services** | **420.6** | **8.0** | | **-10.0** | **418.6** |
| Ground Network | 255.6 | | | 10.0 | 245.6 |
| Mission Control and Data Systems | 135.8 | ***8.0*** | | 3.3 | 147.1 |
| Space Network Customer Services | 29.2 | | | -3.3 | 25.9 |

## CHANGE FROM FY 1997 BUDGET ESTIMATE

Funding for Mission Communications totals $418.6 million, a net reduction of $2 million from the request, which is made up of a reduction of $10 million within the Ground Network program, offset by a reallocation of ***$8*** million to the Mission Control and Data Systems Program from the Space Access and Technology Program. Funding for Deep Space Network (DSN) Systems within the Ground Network budget element is reduced $10 million, which can be achieved by implementing engineering efficiencies and economies, an action which will have minimal impact to DSN services or overall mission support. In addition, $3.3 million is reallocated from Space Network Customer Services to Mission Control and Data Systems based on reassessment of programmatic requirements. The reallocation of funds from the Space Access and Techology Program will support research and technology development activities in space communications.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Academic programs** ..... | **100.8** | | | **19.6** | **120.4** |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

Funding for Academic Programs is increased $19.6 million, to accommodate direction in House Report 104-812. This increase is made up of the $8 million reallocated from the MTPE program, as noted above, for NASA participation in the development of a national center for science literacy, education and technology. Also included is $2.0 million, as directed in the Conference Report to support initial development of a national prototype space education curriculum and for replication and distribution of that curriculum. Finally, as directed in the Conference Report, $10.0 million is allocated to the Minority University Research Program to achieve a balance between funding levels for the ongoing Education Programs and Minority University Research programs. Of this amount, $8.9 million is allocated to the Minority University Research Program as directed: as further directed, the remainder has been applied to the Mobile Aeronautics Education Laboratory, a feasibility study for a national residential high school, replication of the Science, Engineering, Mathematics and Aeronautics Academy program and evaluation of the Classroom of the Future's Astronomy Village Program. This **$10** million increase is partially offset by a decrease of $0.4 million which can be accommodated by applying available unobligated and uncosted funding.

## MISSION SUPPORT

The funding level for the Mission Support appropriation of **$2,562.2**s unchanged from the budget request.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Safety, Reliability & Quality Assurance.....** | **36.7** | | | | **36.7** |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

There **is** no change in total funding for activities managed by the Office of Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) and the Office of the Chief Engineer.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Space Communication Services.....** | **291.4** | | | | **291.4** |
| Space network ..... | **185.1** | | | | **185.1** |
| Telecommunications ..... | **106.3** | | | | **106.3** |

**CHANGE FROM FY 1997 BUDGET ESTI**

There is no change in the budget authority planned total funding for Space Communications Services activities. The reimbursable budget authority which complements the NASA direct funding is **$48.3** million.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Construction of facilities** | **155.3** | | | | **155.3** |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

There is no change in total funding for Construction of Facilities activities.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **Research and program management** | **2,078.8** | | | | **2,078.8** |
| Personnel and related cost | 1,611.0 | | | | 1,611.0 |
| Travel | 45.5 | | | | 45.5 |
| Research operati ≅ su, ort. | 422.3 | | | | 422.3 |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

There is no change in funding for Research and Program Management activities.

| | FY 1997 | | | | |
|---|---|---|---|---|---|
| | BUDGET ESTIMATE | SPACE ACCESS & TECHNOLOGY | APPROP TRANSFER | OTHER CHANGES | CURRENT ESTIMATE |
| **INSPECTOR GENERAL** | **17.0** | | | | **17.0** |

**CHANGE FROM FY 1997 BUDGET ESTIMATE**

There is no change in funding for Inspector General activities.

Special Issues

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1998 BUDGET ESTIMATES

## FULL-COST BUDGETING

NASA is currently developing a methodology to generate the budget on a "full-cost" basis, in order to better utilize and assess its overall resources and institutional base. This full-costing of all NASA Enterprises, programs and projects is part of an overall initiative, integrating full-cost management, budgeting and accounting, consistent with its strategic planning, and recommended by the agency's Zero-Base Review in 1995. Pending Congressional approval, NASA is planning to implement this initiative, with its attendant change in appropriation structure, in the FY 1999 budget to Congress.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1998 BUDGET ESTIMATES

MULTI-YEAR APPROPRIATIONS
(IN MILLIONS OF REAL YEAR DOLLARS)

NASA is seeking multi-year appropriations for the following selected projects:

| | FY 1998 | FY 1999 | FY 2000 | FY 2001 | FY 2002 | FY 2003 |
|---|---|---|---|---|---|---|
| INTERNATIONAL SPACE STATION | 2,121.3 | 2,109.2 | 1,914.6 | 1,596.8 | 1,147.0 | |
| SPACE INFRARED TELESCOPE FACILITY (SIRTF) | 81.4 | 134.5 | 130.0 | 117.3 | 25.8 | |
| DEVELOPMENT | 81.4 | 126.5 | 108.1 | 97.6 | 19.2 | |
| LAUNCH SERVICES | | 8.0 | 21.9 | 19.7 | 6.6 | |
| STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA) | 45.8 | 56.5 | 48.8 | 32.4 | | |
| X-33 EXPERIMENTAL LAUNCH VEHICLE | 329.8 | 313.9 | 75.0 | | | |
| TRACKING & DATA RELAY SATELLITE REPLENISHMENT | 157.5 | 120.4 | 58.0 | 70.0 | 98.2 | 52.6 |
| DEVELOPMENT | 107.0 | 69.3 | 37.8 | 69.8 | 16.4 | 19.9 |
| LAUNCH SERVICES | 50.5 | 51.1 | 20.2 | 50.2 | 81.8 | 32.7 |

## National Aeronautics and Space Administration

### Major NASA Development Programs
### Program Cost Estimates

This special section of the FY 1998 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 1996 and prior fiscal year budget authority are the "actual" amounts. The FY 1997 amounts are consistent with the proposed **NASA** Operating Plan as of December 1996. The amounts for FY 1998 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 1994 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 reader is referred to the **NASA** Program Status Reports, a biannual document published by **NASA,** for the most accurate information available to **NASA** on the amounts incurred or to be incurred.) 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 two 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.

## High Speed Research Program

The High Speed Research Program is a cooperative government-industry program to develop the technologies required by U.S. firms to design and build an environmentally compatible and economically competitive high-speed civil transport aircraft for the post-2000 period. The program consists of two phases. Phase I was initiated in FY 1990. Research was initiated at that time into environmental issues, such as atmospheric effects (e.g., ozone depletion), take-off and landing noise levels, and sonic booms for overland flight. Potential technology solutions have also been investigated. Phase II began in FY 1994, following a presentation of *the* encouraging preliminary results from Phase I activities. This phase involves both government funding and industry contributions of facilities, personnel, and supporting R&D. Development and validation of specific airframe and engine designs, design tools, and technologies for manufacturing processes are underway. This phase will conclude in 2002. It should be noted that the government funding does not provide for the development of a prototype aircraft.

The HSR program previously included the Environmental Research Aircraft and Remote Sensor Technology (ERAST) project element, with the objective of developing the technology for remotely piloted aircraft to serve as platforms to sample the stratospheric atmosphere for exhaust gases and particulates. The technology was not developing fast enough to meet the timelines of HSR, so the ERAST program was replanned to develop and commercialize remotely piloted aircraft. The objectives of ERAST no longer support the primary HSR objectives. ERAST has therefore been transferred from HSR into the R&T base, and the associated funding has been deleted from the HSR program accordingly.

The budgetary estimates provided below are the amounts included in the specific budget justification within the Aeronautics section in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts being contributed by industry, or for the use of government facilities and general support used to carry out the research. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL** EXCLUDING CIVIL SERVICE COSTS ($M) | 658.1 | 233.3 | 243.1 | 245.0 | 174.0 | 91.2 | 60.2 | 60.2 | -- | 1,765.1 |
| (ESTIMATED CIVIL SERVICE FTEs) | (1849) | (568) | (573) | (566) | (584) | (514) | (481) | (468) | | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | 112.7 | 41.0 | 44.2 | 45.9 | 46.2 | 41.4 | 39.7 | 41.0 | | |

## Advanced Subsonic Technology

The Advanced Subsonic Technology (AST) program is a cooperative government-industry program to develop technologies in areas where such developments will facilitate the economic and technological competitiveness of U.S. subsonic aircraft producers. These developments include not only airframe. engine, and avionics technology improvements, but also short-haul aircraft, environmental studies, efficiency and safety improvements, advanced air traffic technology, and aircraft design and manufacturing tools. This systems technology program was preceded by activities funded within the research and technology base for many years; the decision to create a focused program was made in the FY 1991 budget. The specific objectives set forth for this program are intended to be completed by FY 2004.

In FY 1996, the Fly-by-light/Power-by-Wire (FBL/PBW) element of AST program was terminated and the out-year composite fuselage project was eliminated. Funding for the AST program has been reduced to reflect these changes. In addition, a new change in the AST program is being is being discussed that will shift the emphasis from economics to revolutionary advances in the software tools necessary to design, manufacture and certify aviation systems in order to provide significant reductions in the cost of aircraft.

The budgetary estimates provided below are the amounts included in the specific budget justification within the Aeronautics section in the Science, Aeronautics and Technology appropriation for this program. As such, they do not include the amounts being contributed by industry, or for the use of government facilities and general and administrative support used to carry out the research. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 232.5 | 169.8 | 173.6 | 211.1 | 187.0 | 144.2 | 163.3 | 94.0 | 107.1 | 1,482.6 |
| (ESTIMATED C M L SERVICE FTEs) | (830) | (536) | (597) | (541) | (493) | (443) | (389) | (342) | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 53.4 | 38.7 | 46.1 | 43.9 | 39.1 | 35.7 | 32.1 | 30.0 | | |

## 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 $2 1.O-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, President Clinton 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 the Human Space Flight appropriation. Previous budgets provided funding for Space Station related research and payloads in the Science, Aeronautics and Technology appropriation. This past year 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 annual $2.1 billion budget. The FY 1998 budget reflects that consolidation by funding the total annual $2.1 billion budget within the Space Station budget line of the Human Space Flight appropriation account. The research and technology elements of the program, including Mir research and support, utilization support, life and microgravity sciences payloads and research, and the station-related space product development activities, are now included in the Research line. The FY 1998 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 date when the completion of the U.S. element assembly milestone in June 2002 is accomplished. They 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. The present cost estimate for the average costs of the 18 Space Shuttle flights for assembly of the U.S. elements by June 2002 is $7.4 billion. Four flights largely dedicated to partner elements are estimated at $1.7 billion. An additional 6 Shuttle flights will be made for research and technology utilization purposes during the assembly period: at average costs, these utilization flights are estimated at $2.5 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 | Balance * to June 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PROGRAM ELEMENTS WITHIN $2.1 BILLION ANNUAL FUNDING CAP** | | **2,106.0** | **2,112.9** | **2,143.6** | **2,148.6** | **2,121.3** | **2,109.2** | **1,914.6** | **1,596.8** | **1,147.0** | **17,400.0** |
| **HUMAN SPACE FLIGHT **** | **10,234.1** | **2,106.0** | **2,112.9** | **2,143.6** | **2,148.6** | **2,121.3** | **2,109.2** | **1,914.6** | **1,596.8** | **1,147.0** | **27,634.1** |
| SPACE STATION | 10,234.1 | 2,106.0 | 2,112.9 | 2,143.6 | 2,148.6 | 2,121.3 | 2,109.2 | 1,914.6 | 1,596.8 | 1,147.0 | 27,634.1 |
| DEVELOPMENT | 9,190.4 | 1,918.2 | 1,749.4 | 1,746.2 | 1,766.3 | 1,386.1 | 898.4 | 651.5 | 285.1 | 105.5 | 19,697.1 |
| OPERATIONS | | | 108.9 | 120.0 | 177.6 | 490.1 | 714.6 | 750.6 | 750.6 | 637.4 | 3749.8 |
| RESEARCH | 121.0 | 187.8 | 254.6 | 277.4 | 204.7 | 245.1 | 496.2 | 512.5 | 561.1 | 404.1 | 3264.5 |
| OTHER | 922.7 | | | | | | | | | | 922.7 |
| (ESTIMATED CIVIL SERVICE FTEs) | (3,245) | (1,283) | (1,441) | (1,934) | (2,188) | (2,425) | (2,309) | (2,195) | (2,166) | (1,586) | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) *** | | 85.9 | 102.6 | 139.6 | 168.8 | 196.6 | 182.8 | 176.7 | 179.0 | 139.0 | |

* Balance of estimate is for 9 months of the fiscal year, through June 2002 (U.S. assembly complete)

** 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.

*** Civil Service estimates include only FTEs for the International Space Station within Human Space Flight

## 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 will be in early FY 1998. The budgetary estimates provided below include 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 runout budget estimate of $970.6 million reflects a decrease of $59.8 million from the FY 1997 budget estimate. The decrease is due to a reduction of project reserves, consistent with expected technical progress. The reserves will remain available at the program level, however, should they be required.

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 Shuffle program.

(Budget Authority in Millions of Dollars) .

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 554.8 | 68.7 | 46.7 | 46.7 | 22.1 | 10.8 | | | | 749.8 |
| IMPLEMENTATION | 58.4 | 28.3 | 48.7 | 49.5 | 28.2 | 7.7 | | | | 220.8 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 613.2 | 97.0 | 95.4 | 96.2 | 50.3 | 18.5 | | | | 970.6 |
| (ESTIMATED CIVIL SERVICE FTEs) | (410) | (55) | (51) | (26) | (16) | (16) | | | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 22.5 | 4.0 | 3.9 | 2.1 | 1.3 | 1.2 | | | | |

## Super Lightweight Tank

The design and development of a lighter external tank for the Space Shuttle was undertaken in 1993 after tests of new aluminum-lithium materials indicated that a significantly lighter external tank could be produced. The anticipated weight savings of approximately 7500 pounds would recover some of the ascent performance losses resulting from safety and reliability improvements instituted after the Challenger disaster. Coupled with other performance gains, the super lightweight tank will facilitate the Space Shuttle's operations at new higher inclination orbit established in 1993 for the international Space Station. The first launch of a Space Shuttle with the new tank is planned for late 1997. In addition to the design and development costs, the figures shown below as "recurring cost" provide the estimate of the funding required for the external tank program's production of the new tanks. The estimates include the additional material cost which will be incurred in the production of subsequent tanks. The aluminum-lithium material is a specialty metal produced to rigorous specifications and accordingly costs more than the aluminum used at present.

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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT COST | 92.0 | 30.7 | 17.5 | 9.2 | 6.8 | | | | *43.8 | 200.0 |
| RECURRING COST | 28.7 | 27.3 | 31.9 | 33.1 | 33.1 | 8.5 | | | Cont. | 162.6 |
| TOT EXCLUDING CIVIL SERVICE COSTS ($M) | 120.7 | 58.0 | 49.4 | 42.3 | 39.9 | 8.5 | | | 43.8 | 362.6 |

*- Undistributed reserve

| | | | | | | |
|---|---|---|---|---|---|---|
| (ESTIMATED CIVIL SERVICE FTEs) | (73) | (78) | (68) | (64) | (37) | (43) |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 5.2 | 5.6 | 5.3 | 5.2 | 2.9 | 3.5 |

## Advanced X-Rav Astrophysics Facility

The design and development of the Advanced X-Ray Astrophysics Facility (AXAF) was approved by Congress in the FY **1989** budget. The AXAF is the third *of* the four "Great Observatories" intended to observe the universe in four electromagnetic spectrum regions: visible, infrared, gamma ray, and x-ray. The initial phase of the AXAF's development was limited to a feasibility demonstration of the new mirror technology required to achieve the AXAF's objectives. A specially designed x-ray calibration facility was constructed to assure the mirrors meet their design specifications. The second phase was approved by Congress after the demonstration mirrors were successfully tested. In **1992,** NASA management directed the restructuring *of* the AXAF program to reduce projected future funding requirements. A two-spacecraft approach was selected, a large imaging spacecraft (**AXAF-I**maging) and a smaller spectroscopy spacecraft (AXAF-Spectroscopy). In **1993,** Congress directed the elimination of the *AXAF-S.* The launch of the AXAF-I spacecraft is scheduled for September **1998** aboard the Space Shuttle, with an Inertial Upper Stage (IUS) providing delivery into a highly elliptical orbit around the **Earth.** 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 **(1998-2002)** 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 provided below 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| ADVANCED TECH DEVELOPMENT | 54.2 | | | | | | | | | 54.2 |
| DEVELOPMENT | 943.8 | 237.6 | 178.6 | 92.2 | | | | | | 1,452.2 |
| MISSION OPS & DATA ANALYSIS | 52.5 | 40.4 | 41.3 | 45.4 | 63.6 | 63.3 | 67.3 | 69.9 | 76.3 | 520.0 |
| UPPER STAGE | 32.6 | 15.3 | 14.5 | 5.3 | | | | | | 67.7 |
| STS LAUNCH SUPPORT | | 216.7 | 86.6 | 130.0 | | | | | | 433.3 |
| TRACKING & DATA SUPPORT | .3 | .5 | .4 | .3 | .2 | .2 | .2 | .2 | 1.4 | 3.7 |
| CONSTRUCTION OF FACILITIES | 17.7 | | | | | | | | | 17.7 |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 1,101.1 | 510.5 | 321.4 | 273.2 | 63.8 | 63.5 | 67.5 | 70.1 | 77.7 | 2,548.8 |
| (ESTIMATED CIVIL SERVICE FTEs) | (1052) | (269) | (235) | (183) | (70) | (36) | (36) | (36) | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 61.5 | 19.4 | 18.1 | 14.8 | 5.5 | 2.9 | 3.0 | 3.2 | | |

## 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 simply "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 FY 1998 budget proposes multi-year appropriations for development of SIRTF. This will ensure the stability to manage and execute this program within its budget and schedule commitments.

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 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| ATD | | 15.0 | 24.9 | | | | | | | 39.9 |
| DEVELOPMENT | | | | 81.4 | 126.5 | 108.1 | 97.6 | 19.2 | | 432.8 |
| MISSION OPS & DATA ANALYSIS | | | | | | | | 20.0 | 101.2 | 121.2 |
| LAUNCH SUPPORT | | | | | 8.0 | 21.9 | 19.7 | 6.6 | | 56.2 |
| TRACKING & DATA SUPPORT | | | | | | | | | | TBD |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | | 15.0 | 24.9 | 81.4 | 134.5 | 130.0 | 117.3 | 45.8 | 101.2 | 650.1 |
| (ESTIMATED CIVIL SERVICE FTEs) | | (3) | (2) | (2) | (2) | (2) | (2) | (2) | | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | | |

## 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 October 2000, using a Delta II launch vehicle. The estimates provided.below include funding for the experiment development activities, a minimum of 16 months of mission operations, and the launch services.

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 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 219.8 | 51.5 | 59.6 | 45.6 | 44.0 | 35.8 | 4.1 | | | 460.4 |
| MISSION OPS & DATA ANALYSIS | | | | | | | 20.8 | | | 20.8 |
| LAUNCH SUPPORT | | | 6.8 | 14.7 | 18.8 | 16.7 | .2 | | | 57.2 |
| TRACKING & DATA SUPPORT | | | | | | | TBD | | | TBD |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 219.8 | 51.5 | 66.4 | 60.3 | 62.8 | 52.5 | 25.1 | | | 538.4 |
| (ESTIMATED CIVIL SERVICE FTEs) | (62) | (15) | (13) | (13) | (13) | (12) | (12) | | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 3.5 | 1.1 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | | | |

## 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. The development cost for the TIMED mission is capped at $100 million in FY 1994 dollars. TIMED will be 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 is scheduled for launch in January 2000 aboard a Med-Lite Class launch vehicle. TIMED will begin 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.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | | 18.2 | 48.2 | 47.3 | 15.6 | | | | 129.3 |
| MISSION OPS & DATA ANALYSIS | | | | | | 9.2 | 12.8 | 9.0 | 7.2 | 38.2 |
| LAUNCH SUPPORT | | | | 8.7 | 11.5 | 6.1 | | | | 26.3 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | | | 26.9 | 56.9 | 58.8 | 30.9 | 12.8 | 9.0 | 7.2 | 193.8 |
| (ESTIMATED CIVIL SERVICE FTEs) | | (7) | (14) | (19) | (19) | (18) | (8) | (8) | | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | | 0.5 | 1.1 | 1.5 | 1.5 | 1.5 | 0.7 | 0.8 | | |

## Global Geospace Science Missions

The development of the two Global Geospace Science (GGS) missions was approved by Congress in the budget for 1989. The Wind and Polar spacecraft are parts of a coordinated international science program to improve our understanding of the complex interactions between the sun and the Earth. Nineteen instruments aboard the two spacecraft will make measurements of the interaction between the solar wind with the Earth's magnetic field. The Wind spacecraft was launched successfully on a Delta I1 launch vehicle in November 1994. The Polar spacecraft was launched successfully in February 1996, also on a Delta II. The budgetary estimates provide for the experiment and spacecraft development, a 2.5-year period of mission operations. the launch services, and unique tracking and data acquisition support required during the mission.

The budgetary estimates provided below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 452.7 | | | | | | | | | 452.7 |
| MISSION OPS & DATA ANALYSIS | 17.2 | 26.5 | 25.5 | 15.7 | | | | | | 84.9 |
| LAUNCH SUPPORT | 116.6 | 3.0 | | | | | | | | 119.6 |
| TRACKING & DATA SUPPORT | 26.1 | 0.6 | 0.1 | 0.1 | 0.1 | | | | | 27.0 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 612.6 | 30.1 | 25.6 | 15.8 | 0.1 | | | | | 684.2 |
| (ESTIMATED C M L SERVICE FTEs) | (684) | (22) | (5) | (10) | (10) | | | | | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | 38.7 | 1.6 | 0.4 | 0.8 | 0.8 | | | | | |

## Collaborative Solar Terrestrial Research Program

The Collaborative Solar Terrestrial Research (COSTR)program is another key U.S. contribution to the international solar terrestrial research program. Beginning in FY 1987, funding provided for this program has enabled NASA to provide instruments and launch support for international spacecraft. In return, the U.S. obtains access to the science data collected by the five European Space Agency spacecraft and one Japanese spacecraft. The initial launch was carried out in July 1992 with the launch of the Japanese Geotail spacecraft on a U.S.-funded Delta II. The December 1995 launch of the ESA Solar and Heliospheric Observatory (SOHO) was on a U.S.-funded Atlas IIAS. Mission operations and data analysis provides for spacecraft operations, the operations support to the U.S. furnished instruments and the analysis of the scientific data gathered by them.

The four Cluster spacecraft were launched in May **1996,** on an Ariane V; however the launch failed and the payload was lost. Options for recovery of the Cluster mission science are under review by NASA and ESA.

The budgetary estimates provided below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts being contributed by international participants, and 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 331.0 | | | | | | | | | 331.0 |
| MISSION OPS & DATA ANALYSIS | 28.9 | 31.9 | 28.4 | 8.5 | | | | | | 97.7 |
| LAUNCH SUPPORT | 176.1 | | | | | | | | | 176.1 |
| TRACKING & DATA SUPPORT | 38.8 | 1.2 | 0.1 | 0.1 | | | | | | 40.2 |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 574.8 | 33.1 | 28.5 | 8.6 | | | | | | 645.0 |
| (ESTIMATED CIVIL SERVICE FTEs) | (446) | (25) | (26) | (24) | (14) | (12) | | | | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | 25.2 | 1.8 | 2.0 | 1.9 | 1.1 | 1.0 | | | | |

## 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| **X-Ray Timing Explorer** | 253.1 | 11.6 | 10.2 | 7.3 | 4.8 | 3.3 | | | | 290.3 |
| **Advanced Composition Explorer** | 110.2 | 33.7 | 35.9 | 12.6 | 7.5 | 7.7 | 3.7 | 3.9 | | 215.2 |
| **Far Ultraviolet Spectroscopy Explorer** | .5 | 70.8 | 22.6 | 42.1 | 9.6 | 9.4 | 9.4 | 7.0 | | 171.4 |
| **Medium Explorers** | | 13.7 | 45.2 | 62.4 | 87.8 | 103.3 | 101.8 | 118.5 | **CONT** | |
| **Small Explorers** | | 50.8 | 59.7 | 56.8 | 65.7 | 74.5 | 85.5 | 86.8 | **CONT** | |
| **University Explorers** | | 12.3 | 7.1 | 13.3 | 11.8 | 8.3 | 6.5 | 10.6 | **CONT** | |
| **Planning & Future Developments** | | 6.7 | 5.7 | 6.0 | 8.3 | 5.3 | 4.9 | 5.6 | **CONT** | |
| TOTAL **EXCLUDING CIVIL SERVICE COSTS** ($M) | | 199.6 | 186.4 | 200.5 | 195.5 | 211.8 | 211.8 | 232.4 | **CONT** | |
| **(ESTIMATED CML SERVICE FTEs)** | (1,248) | (100) | (97) | (85) | (79) | (78) | (78) | (78) | **(Cont.)** | |
| **CML SERVICE COMPENSATION ESTIMATE** ($M) | 71.8 | 7.2 | 7.5 | 6.9 | 6.3 | 6.3 | 6.4 | 6.8 | **Cont.** | |

## Advanced Composition Explorer

Development on the Advanced Composition Explorer (ACE)began in FY 1994. The spacecraft is being built by the Johns Hopkins Applied Physics Lab; instruments are being managed by the California Institute of Technology. ACE is scheduled for launch between August 1997 and December 1997 on a Delta II launch vehicle.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 77.3 | 18.5 | 18.7 | 5.5 | | | | | | 120.0 |
| MISSION OPS & DATA ANALYSIS | | | 1.6 | 6.3 | 7.2 | 7.4 | 3.6 | 3.8 | | 29.9 |
| LAUNCH SUPPORT | 28.6 | 10.9 | 12.0 | | | | | | | 51.5 |
| TRACKING & DATA SUPPORT | 4.3 | 4.3 | 3.6 | .8 | .3 | .3 | .1 | .1 | | 13.8 |
| TOTAL | 110.2 | 33.7 | 35.9 | 12.6 | 7.5 | 7.7 | 3.7 | 3.9 | | 215.2 |

## Far Ultraviolet Spectroscopic Explorer

Development on the Far Ultraviolet Spectroscopy Explorer (FUSE)began in FY 1996. The FUSE mission has been restructured from a Delta-class explorer in order to reduce costs and accelerate the launch date from CY 2000 to November 1998. FUSE is being managed by Johns Hopkins University, with contributions from the University of Colorado, the University of California-Berkeley, Orbital Sciences Corp., Canada and France.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 56.6 | 22.0 | 26.8 | 2.6 | | | | | 108.0 |
| MISSION OPS & DATA ANALYSIS | | | | | 7.0 | 9.4 | 9.4 | 7.0 | | 32.8 |
| LAUNCH SUPPORT | .5 | 14.2 | .6 | 15.3 | | | | | | 30.6 |
| TOTAL | .5 | 70.8 | 22.6 | 42.1 | 9.6 | 9.4 | 9.4 | 7.0 | | 171.4 |

## X-Ray Timing Explorer

**Development on the X-Ray Timing Explorer (XTE) began in FY 1990. The spacecraft was an in-house build at the Goddard Space Flight Center; instruments were developed by the principal investigators. The XTE was launched successfully in December 1995 on a Delta II launch vehicle.**

**(Budget Authority in Millions of Dollars)**

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 194.2 | | | | | | | | | 194.2 |
| MISSION OPS & DATA ANALYSIS | 1.0 | 10.0 | 9.9 | 7.0 | 4.8 | 3.3 | | | | 36.0 |
| LAUNCH SUPPORT | 45.5 | | | | | | | | | 45.5 |
| TRACKING & DATA SUPPORT | 12.4 | 1.6 | 0.3 | 0.3 | | | | | | 14.6 |
| TOTAL | 253.1 | 11.6 | 10.2 | 7.3 | 4.8 | 3.3 | | | | 290.3 |

## 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 Kuiper was a Lockheed C-141A aircraft with a 0.9-meter reflecting telescope, used to conduct scientific investigations at infrared and submillimeter wavelengths. 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). The initial operational date for SOFIA will be at the end of 2000. The FY 1998 budget proposes multi-year appropriations for development of SOFIA. This will ensure the stability to manage and execute this program within its budget and schedule commitments.

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 Suborbital program within the Space Science section.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 30.0 | 21.3 | 45.8 | 56.5 | 48.8 | 32.4 | | | 234.8 |
| MISSION OPERATIONS | | | | | | | | 36.6 | CONT. | CONT. |
| TOTAL EXCLUDING CML SERVICE COSTS | | 30.0 | 21.3 | 45.8 | 56.5 | 48.8 | 32.4 | 36.6 | | |
| (ESTIMATED CIVIL SERVICE FTEs) | (6) | (13) | (15) | (15) | (15) | (15) | (15) | (10) | | |
| CML SERVICE COMPENSATION ESTIMATE ($M) | 0.5 | 0.9 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 0.9 | | |

## CASSINI

The Cassini mission will provide intensive, long term observations of Saturn's atmosphere. rings, magnetosphere and moons. The Huygens Probe will conduct direct physical and chemical analyses of the atmosphere of Saturn's moon, Titan. Cassini was approved as a new start by Congress in the FY 1990 budget. At the time it was initiated, a second spacecraft. the Comet Rendezvous and Asteroid Flyby (CRAF) was included. Congressionally-imposed reductions to FY 1992-93 funding requirements led to the termination of the CRAF mission and the deferral of the Cassini launch from April 1996 to October 1997. The Cassini program later underwent a significant redesign in early 1992 to reduce total program cost. mass and power requirements, while maintaining the October 1997 launch aboard a Titan IV launch vehicle. The spacecraft will arrive at Saturn in 2004 and begin a four year study of the Saturnian system. The program involves significant cooperation from international partners as well as U.S. government partners. The European Space Agency is providing the Huygens Probe and the Italian Space Agency is contributing the High Gain/Low Gain antenna for the spacecraft. There are twelve science instruments on the orbiter and six on the probe from international principal Investigators. The Titan IV launch vehicle is being procured from the Department of Defense, and the Radioisotope Heater Units (RHUs) and Radioisotope Thermoelectric Generators (RTGs) are being procured by NASA from the Department of Energy.

The budgetary estimates provided below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts being contributed by the international participants, or 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 within the Space Science section.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 1,109.8 | 191.5 | 89.6 | 9.0 | | | | | | 1,399.9 |
| MISSION OPS & DATA ANALYSIS | | | | 38.1 | 55.8 | 55.0 | 56.6 | 63.8 | 466.7 | 736.0 |
| LAUNCH SUPPORT | 206.1 | 88.2 | 95.2 | 39.6 | | | | | | 429.1 |
| TRACKING & DATA SUPPORT | 19.6 | 1.8 | 3.0 | 4.7 | 8.8 | 6.2 | 4.5 | 5.0 | | 53.6 |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 1,335.5 | 281.5 | 187.8 | 91.4 | 64.6 | 61.2 | 61.1 | 68.8 | 466.7 | 2,618.6 |
| (ESTIMATED CIVIL SERVICE FTEs) | (389) | (84) | (24) | (3) | (3) | (3) | (3) | (3) | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 23.7 | 6.1 | 1.9 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | | |

## 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. Two Discovery missions have been launched: **NEAR** in February 1996 and Mars Pathfinder in December 1996. In addition, there are two approved Discovery missions in development: the Lunar Prospector and Stardust. Future missions will be undertaken after selection through a peer review process.

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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| NEAR | 156.7 | 16.9 | 1.6 | 9.7 | 15.0 | 8.8 | .2 | .3 | | 209.2 |
| *MARS* PATHFINDER | 188.8 | 55.8 | 15.0 | 6.0 | .1 | | | | | 265.7 |
| LUNAR PROSPECTOR | | 36.4 | 20.6 | 4.3 | 2.2 | .0 | .0 | .0 | .0 | 63.5 |
| STARDUST | | 27.7 | 62.7 | 56.2 | 23.9 | 3.4 | 3.3 | 3.3 | 25.6 | 206.1 |
| FUTURE MISSIONS DEVELOPMENT | | .7 | 4.8 | 64.2 | 120.7 | 127.5 | 132.6 | 137.6 | CONT | |
| FUTURE MISSIONS MO&DA | | | | | 3.2 | 9.4 | 11.0 | 11.4 | CONT | |
| FUTURE MISSIONS ELVs | | | | 6.0 | 19.6 | 36.5 | 43.5 | 67.2 | CONT | |
| TOTAL | | 137.5 | 104.7 | 146.4 | 184.7 | 185.6 | 190.6 | 219.8 | CONT | |
| (ESTIMATED CIVIL SERVICE FTEs) | (31) | (2) | (7) | (7) | (7) | (7) | (7) | (7) | (Cont.) | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | 2.2 | 0.1 | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | Cont. | |

## Mars Pathfinder

The Mars Pathfinder was approved as a new start in FY 1994 as one of the initial missions in the Discovery Program. The Mars Pathfinder mission .will demonstrate a unique cruise, entry, descent, and landing system approach that will be available for future missions to Mars. Mars Pathfinder was launched in December 1996 on a Delta II expendable launch vehicle. The mission is being conducted as an in-house effort at the Jet Propulsion Laboratory. Portions of the science instruments were provided by Germany and Denmark.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 140.5 | 33.7 | | | | | | | | 174.2 |
| MICROROVER | 17.2 | 5.8 | 2.0 | | | | | | | 25.0 |
| MISSION OPS & DATA ANALYSIS | | | 9.6 | 5.8 | 0.1 | | | | | 15.5 |
| LAUNCH SUPPORT | 31.0 | 16.1 | 3.2 | | | | | | | 50.3 |
| TRACKING & DATA SUPPORT | 0.1 | 0.2 | 0.2 | 0.2 | | | | | | 0.7 |
| TOTAL | 188.8 | 55.8 | 15 | 6.0 | 2.0 | | | | | 265.7 |

## 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.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 116.6 | 8.3 | | | | | | | | 124.9 |
| MISSION OPS & DATA ANALYSIS | | 4.9 | 1.4 | 9.5 | 14.8 | 8.6 | | | | 39.2 |
| LAUNCH SUPPORT | 40.0 | 3.5 | | | | | | | | 43.5 |
| TRACKING & DATA SUPPORT | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | | 1.6 |
| TOTAL | 156.7 | 16.9 | 1.6 | 9.7 | 15.0 | 8.8 | 0.2 | 0.3 | | 209.2 |

## 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 is designed to search for resources on the Moon, with special emphasis on the search for water in the shaded polar regions. Ames Research Center is managing the mission, and Lockheed Martin will provide the spacecraft, instruments, launch and operations. Launch will be on a Lockheed Launch Vehicle-I1 (LLV-II) and is planned for September 1997. Launch costs are included in the development cost. Tracking and communications support will be provided by the Deep Space Network.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 36.4 | 19.8 | | | | | | | 56.2 |
| MISSION OPS & DATA ANALYSIS | | | .8 | 4.3 | 2.2 | | | | | 7.3 |
| TOTAL | | 36.4 | 20.6 | 4.3 | 2.2 | | | | | 63.5 |

## 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 has 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 will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, the spacecraft will carry three additional scientific instruments. *An* optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) is 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 will be launched on the Med-Lite expendable launch vehicle in February 1999 with return of the samples to Earth in January 2006.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| PHASE A/B | | 9.6 | | | | | | | | 9.6 |
| DEVELOPMENT | | 13.5 | 52.2 | 42.3 | 9.8 | | | | | 117.8 |
| MISSION OPS & DATA ANALYSIS | | | | | 1.6 | 3.4 | 3.3 | 3.3 | 25.6 | 37.2 |
| LAUNCH SUPPORT | | 4.6 | 10.5 | 13.9 | 12.5 | | | | | 41.5 |
| TOTAL | | 27.7 | 62.7 | 56.2 | 23.9 | 3.4 | 3.3 | 3.3 | 25.6 | 206.1 |

## 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 Orbiter and Lander were approved in FY 1995. Future small missions are targeted for launch in the launch windows that occur approximately every two years.

The budgetary estimates below are the amounts indicated in the budget justification within the Space Science section in the Science, Aeronautics and Technology appropriation. The specific write-ups for the Mars Global Surveyor and Mars 98 Orbiter/Lander missions include the amounts for the development of the spacecraft and instruments, *two* years of mission operations, and launch services. They do not include costs for the use of government facilities and general and administrative support used to carry out the program. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| MARS *GLOBAL* SURVEYOR | 94.8 | 82.9 | 23.1 | 19.9 | 10.6 | | | | | 231.3 |
| 98 *MARS* ORBITER/LANDER | | 59.8 | 116.7 | 79.3 | 30.9 | 21.7 | 22.2 | 22.7 | | 353.3 |
| FUTURE MISSIONS | | 1.4 | 3.1 | 103.3 | 151.6 | 212.1 | 215.4 | 214.7 | Cont. | 901.6 |
| TOTAL, EXCLUDING CIVIL SERVICE COSTS ($M) | 94.8 | 145.1 | 142.9 | 202.5 | 193.1 | 233.8 | 237.6 | 237.4 | | 1487.2 |
| (ESTIMATED CIVIL SERVICE FTEs) | (37) | (6) | (8) | (7) | (7) | (7) | (7) | (7) | (Cont.) | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 2.6 | 0.4 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 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. 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL. |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 72.6 | 58.1 | | | | | | | | 130.7 |
| MISSION OPS & DATA ANALYSIS | | | 16.4 | 19.6 | 10.4 | | | | | 46.4 |
| LAUNCH SUPPORT | 21.8 | 24.4 | 6.4 | | | | | | | 52.6 |
| TRACKING & DATA SUPPORT | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | | | | | 1.6 |
| TOTAL | 94.8 | 82.9 | 23.1 | 19.9 | 10.6 | | | | | 231.3 |

## 98 Mars Orbiter/Lander

The 98 Mars Orbiter and Lander are the first follow-on missions in the Mars Surveyor program. The Orbiter will be launched on a Med-Lite launcher in December 1998, and the Lander will be launched on a Med-Lite in January 1999. Lockheed Martin Aerospace, Denver, was selected competitively to develop these spacecraft. The Orbiter will carry a color imager and a Pressure Modulater Infrared Radiometer (PMIRR),which was also a Mars Observer payload. The Lander will carry a descent imager, a comprehensive volatiles and climate payload, and a Russian LIDAR atmospheric instrument.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 52.4 | 86.9 | 40.5 | 13.3 | | | | | 193.1 |
| MISSION OPS & DATA ANALYSIS | | | | | 10.3 | 21.3 | 21.9 | 22.7 | | 76.2 |
| LAUNCH SUPPORT | | 7.4 | 29.8 | 38.8 | 7.1 | | | | | 83.1 |
| TRACKING & DATA SUPPORT | | | | | 0.2 | 0.4 | 0.3 | | | 0.9 |
| TOTAL | | 59.8 | 116.7 | 79.3 | 30.9 | 21.7 | 22.2 | 22.7 | | 353.3 |

## Future Surveyor Missions

The Mars Surveyor landers planned in future years -- 2001, 2003 and beyond -- will capitalize on the experience of the Mars Pathfinder lander mission launched in November 1996. The small orbiter to be launched in 2003 will draw on the experience of Mars Global Surveyor and carry other scientific instruments into orbit to complete Mars Global Surveyor's science missions. A Mars sample return mission is being considered for the FY 2005 opportunity.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 1.4 | 3.1 | 99.2 | 122.7 | 167.7 | 170.3 | 173.9 | | 738.3 |
| MISSION OPS & DATA ANALYSIS | | | | | | | | | | |
| LAUNCH SUPPORT | | | | 4.1 | 28.9 | 44.4 | 45.1 | 40.8 | CONT | |
| TRACKING & DATA SUPPORT | | | | | | | | | TBD | TBD |
| TOTAL | | 1.4 | 3.1 | 103.3 | 151.6 | 212.1 | 215.4 | 214.7 | | |

## Space Science New Millennium Spacecraft

The New Millennium program is an advanced development effort started in FY 1996 to demonstrate how complex scientific spacecraft--such as those required for planetary missions--can be built for lower mission costs and have short development times, while still possessing considerable scientific merit. The New Millennium Spacecraft program will enable the introduction of the latest technology advances into spacecraft for planetary and outer solar system explorations. 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 the severe budget constraints of the future. In previous years, NASA and the Department of Defense have funded technology developments which offer extraordinary promise. This precursor work on technologies can now be demonstrated in a series of flight technology demonstration missions occurring at a rate of one every 1.5 years, with the initial flight planned for the mid-1998 time frame.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. The program is designed as an ongoing program, and funding is included for development and launch of one mission per every one and one half years, beginning in 1998. 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 first two missions is provided later in this section. 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance |
|---|---|---|---|---|---|---|---|---|---|
| ADVANCED TECH DEVELOPMENT | 10.5 | | | | | | | | |
| NEW MILLENNIUM DEVELOPMENT | | 43.5 | 45.6 | 30.7 | 51.4 | 52.9 | 49.3 | 59.0 | Cont. |
| OUTER PLANET TECHNOLOGY | | | | 25.0 | 25.0 | 50.0 | 50.0 | 50.0 | Cont. |
| ADVANCED RTG | | | 3.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | Cont. |
| CTR FOR INTEG SPACE MICROSYSTEMS | | | | 10.0 | 15.0 | 15.0 | 15.0 | 15.0 | Cont. |
| LAUNCH SUPPORT | | 3.7 | 5.1 | 32.9 | 10.6 | 12.4 | 9.6 | 24.8 | Cont. |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 10.5 | 47.2 | 53.7 | 108.6 | 112.0 | 140.3 | 133.9 | 158.8 | Cont. |
| (ESTIMATED C M L SERVICE FTEs) | | (2) | (4) | (4) | (4) | (4) | (4) | (4) | Cont. |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | |

## Deep Space I

Deep Space I was selected in FY 1996 as the first New Millennium Program mission. The technology to be validated will include solar electric propulsion, an advanced solar array, autonomous primary navigation, 3-D stack flight computer, and miniature imaging camera spectrometer. Spectrum Astro was selected in FY 1996 to integrate the spacecraft. DS I is expected to launch in July, 1998 on a Med-Lite-class Delta launch vehicle. 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 26.3 | 28.9 | 18.1 | | | | | | 73.3 |
| SUPPLEMENTAL TECH DEV | | 7.2 | 6.1 | 1.6 | | | | | | 14.9 |
| MISSION OPS & DATA ANALYSIS | | | | | 3.6 | 2.1 | | | | 5.7 |
| LAUNCH SUPPORT | | 3.7 | 5.1 | 31.9 | | | | | | 40.7 |
| TRACKING & DATA SUPPORT | | | 0.1 | 0.2 | 0.1 | | | | | 0.4 |
| TOTAL | | 37.2 | 40.2 | 51.8 | 3.7 | 2.1 | | | | 135.0 |

## Deep Space II

Deep Space II was selected in FY 1996 as the second of the series of missions under the New Millennium Program. DS II is designed to develop and validate technologies and systems required to deliver multiple small packages to the surface and/or subsurface of Mars using direct entry. Some of the technologies to be validated include a microtelecommunications system, power electronics, a microcontroller, flexible interconnects for system cabling, a meteorological, high-g pressure sensor, and a sample/water experiment. DS II will be attached to ("piggyback" on) the Mars 98 Lander, which is scheduled to launch in January 1999.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | BTC | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | | 6.8 | 8.4 | 3.5 | 1.8 | .4 | | | | 20.9 |
| SUPPLEMENTAL TECH DEV | | 1.8 | .5 | 1.0 | | | | | | 3.3 |
| MISSION OPS & DATA ANALYSIS | | | | .2 | .2 | .2 | | | | .6 |
| TOTAL | | 8.6 | 8.9 | 4.7 | 2.0 | .6 | | | | 24.8 |

## 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 Mission to Planet Earth 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 long-term (15 years), 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. Although EOS was understood to be a program having a 15-year period of night operations, 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 series (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 1998 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 Mission to Planet Earth 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's activities previously funded by the Department of Defense.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. 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 2002. 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 Mission to Planet Earth section.

(Budget Authority in Millions of Dollars)

| Earth Observing System | Prior | 1996 | 1997 | 1998 | 1999 | 2000 | Subtotal Through Fy 2000 | 2001 | 2002 | Total Through FY 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| MORNING SERIES | 843.9 | 178.7 | 82.8 | 49.1 | 39.0 | 160.6 | 1,354.1 | 199.0 | 195.0 | 1,748.1 |
| AFTERNOON SERIES | 203.2 | 103.7 | 149.7 | 218.0 | 118.1 | 63.3 | 856.0 | 117.0 | 185.6 | 1,158.6 |
| CHEMISTRY | 21.8 | 27.3 | 63.3 | 100.6 | 149.1 | 143.6 | 505.7 | 76.0 | 49.2 | 630.9 |
| SPECIAL SPACECRAFT | 142.6 | 60.5 | 83.1 | 91.7 | 123.8 | 146.3 | 648.0 | 121.1 | 95.8 | 864.9 |
| LANDSAT 7 DEVELOPMENT | 184.0 | 85.2 | 76.2 | 52.1 | 2.0 | 1.5 | 401.0 | | | 401.0 |
| ALGORITHM DEVELOPMENT | 194.7 | 73.3 | 84.9 | 102.7 | 131.2 | 153.5 | 740.3 | 134.6 | 136.4 | 1.011.3 |
| TECHNOLOGY INFUSION | 10 | 25.5 | 46.7 | 65.5 | 55.5 | 65.5 | 259.7 | 65.5 | 65.5 | 390.7 |
| EOSDIS | 653.2 | 247.2 | 254.6 | 244.7 | 287.5 | 271.7 | 1,958.9 | 268.1 | 267.5 | 2,494.5 |
| SUBTOTAL | 2,244.4 | 801.4 | 841.3 | 924.4 | 906.2 | 1,006.0 | 6,723.7 | 981.3 | 995.0 | 8,700.0 |
| PHASE B | 41.0 | | | | | | 41.0 | | | 41.0 |
| SPACE STATION PLATFORM | 104.0 | | | | | | 104.0 | | | 104.0 |
| TRACKING AND DATA SUPPORT | | .4 | | | .1 | .1 | .6 | .2 | .1 | .9 |
| EOS SCIENCE | 37.3 | 16.7 | 22.4 | 30.3 | 32.5 | 42.5 | 181.7 | 43.7 | 39.7 | 265.1 |
| LAUNCH SERVICES | 67.1 | 86.8 | 65.5 | 84.3 | 55.8 | 47.2 | 406.7 | 57.5 | 57.3 | 521.5 |
| CONSTRUCTION OF FACILITIES | 79.7 | 17.0 | | | | | 96.7 | | | 96.7 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 2,573.5 | 922.6 | 930.5 | 1,039.0 | 994.6 | 1,095.8 | 7,554.4 | 1082.7 | 1092.1 | 9,729.2 |
| (ESTIMATED C M L SERVICE FTEs) | (1954) | (647) | (821) | (842) | (838) | (791) | | (792) | (792) | |
| C M L SERVICE COMPENSATION ESTIMATE ($M) | 125.7 | 46.6 | 63.3 | 68.2 | 66.3 | 63.6 | | 65.4 | 69.3 | |

## Earth Probes

The Earth Probes program consists of spacecraft and instrument developments to address specific, highly-focused mission requirements in Earth science research. They are complementary to the scientific data-gathering activities carried out within the EOS program. The currently approved Earth probes are the Total Ozone Mapping Spectrometer (TOMS), NASA Scatterometer (NSCAT), and the Tropical Rainfall Measuring Mission. The Earth System Science Pathfinder missions will be funded to take advantage of the new technologies in spacecraft and instrument design being developed by other federal agencies and by NASA. The Experiments of Opportunity funding will accommodate opportunities to provide flight instruments and technologies on non-Mission to Planet Earth missions, foreign or domestic, or on airborne experiments. The Lewis and Clark missons were transferred from Advanced Concepts and Technology. The "lightSAR" program is consistent with direction included in House Report 104-812.

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, launch services, related funding included in the Earth Observing System program, NASA civil service work force salary and expenses, 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 Mission to Planet Earth section.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| NASA SCATTEROMETER | 206.8 | 3.2 | | | | | | | 210.0 |
| TOTAL OZONE MAPPING SPECTROMETER | 104.5 | 3.0 | 1.0 | 5.7 | 3.4 | 4.7 | | | 122.3 |
| TROPICAL RAINFALL MEASURING MISSION | 202.3 | 25.5 | 17.7 | | | | | | 245.5 |
| LEWIS & CLARK | 74.4 | 42.6 | 5.0 | 5.0 | 5.0 | | | | 132.0 |
| "LightSAR" | | | 12.0 | | | | | | 12.0 |
| EARTH SYSTEM SCIENCE PATHFINDERS | | 1.0 | 19.4 | 29.4 | 73.4 | 73.3 | 73.2 | 73.2 | Continues |
| EXPERIMENTS OF OPPORTUNITY | | 4.8 | 2.1 | .6 | .4 | 5.3 | 5.3 | 5.3 | Continues |

## 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 EO-2 mission has not been selected.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| EO-1 | | 7.8 | 35.0 | 26.0 | 5.0 | | | |
| EO-2 (*PLANNING ESTIMATE*) | | | | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| LAUNCH SERVICES | | 2.3 | 6.0 | 15.5 | 12.0 | 2.3 | 38.1 | |
| NMP TECHNOLOGY & FUTURE FLIGHTS | 1.0 | 12.2 | | 10.0 | 31.0 | 36.0 | 36.0 | 36.0 |
| SENSOR & DETECTOR TECHNOLQGY | | 5.5 | 4.7 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 |
| INSTRUMENT INCUBATOR | | | 7.0 | 20.0 | 10.0 | 20.0 | 20.0 | 20.0 |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 1.0 | 27.8 | 52.7 | 81.0 | 67.5 | 67.8 | 103.6 | 65.5 |

## Scatterometer

NASA began the development of the NASA Scatterometer (NSCAT) in October 1984 as a host instrument on the Navy Remote Sensing Satellite (N-ROSS). The N-ROSS program was canceled in March 1988. In August 1989. NSCAT was selected by the Japanese space agency for their planned Advanced Earth Observing System (ADEOS) mission. The instrument's design was altered to allow it to be accommodated on the ADEOS. The Japanese launched the ADEOS spacecraft on their H-II launch vehicle on August 17, 1996.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 206.8 | 3.2 | | | | | | | 210.0 |
| MISSION OPERATIONS | | 2.4 | 4.2 | 4.2 | 3.0 | | | | 13.8 |
| SCIENCE TEAMS | | | 4.6 | 3.9 | 3.9 | | | | 12.4 |
| ***TOTAL*** EXCLUDING C M L SERVICE COSTS ($M) | 206.8 | 5.6 | 8.8 | 8.1 | 6.9 | | | | 236.2 |

## Total Ozone Mapping Spectrometer

The TOMS Earth Probes program 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. Flight model 5 is currently planned for a cooperative mission with the Russian Space Agency in the year 2000.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 104.5 | 3.0 | 1.0 | 5.7 | 3.4 | 4.7 | | | 122.3 |
| MISSION OPERATIONS | 9.2 | 1.3 | 1.0 | 2.8 | 1.8 | 3.5 | 3.5 | 3.6 | 26.7 |
| SCIENCE TEAMS | | 1.3 | 1.0 | 2.8 | 1.8 | 3.5 | 3.5 | 3.6 | 17.5 |
| SELV | 16.7 | | | | | | | | 16.7 |
| TRACKING (TOMS EARTH PROBE) | 4.4 | .7 | .3 | .3 | .3 | | | | 6.0 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 134.8 | 6.3 | 3.3 | 11.6 | 7.3 | 11.7 | 7.0 | 7.2 | 189.2 |
| (ESTIMATED CIVIL SERVICE FTEs) | (126) | (12) | (8) | (10) | (11) | (9) | (1) | (1) | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 8.1 | 0.9 | 0.6 | 0.8 | 0.9 | 0.7 | 0.1 | 0.1 | |

## Tropical Rainfall Measuring Mission

The development of the Tropical Rainfall Measuring Mission (TRMM) 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 is being built in-house at the Goddard Space Flight Center. The Japanese are building 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 TRMM is currently planned for launch in November 1997 on the Japanese H-II launch vehicle. The EOS Data and Information System will have a specific capability for disseminating TRMM data.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| DEVELOPMENT | 202.3 | 25.5 | 17.7 | | | | | | | 245.5 |
| EOS-FUNDED INSTRUMENTS/SCIENCE/DIS | [18.0] | [21.9] | [10.3] | [8.8] | [12.6] | | | | | [71.6] |
| MISSION OPERATIONS | | | .8 | 7.9 | 7.8 | 7.7 | 8.3 | 10.6 | 6.2 | 49.3 |
| SCIENCE TEAMS | | | .5 | 11.7 | 12.7 | 12.8 | 13.1 | 2.7 | 10.6 | 64.1 |
| RESEARCH & ANALYSIS-FUNDED SCIENCE | 23.6 | 5.9 | 5.9 | | | | | | | 35.4 |
| TRACKING | 8.5 | 2.9 | 2.1 | 1.3 | .2 | .2 | .2 | | | 15.4 |
| TOTAL EXCLUDING C M L SERVICE COSTS ($M) | 234.4 | 34.3 | 27.0 | 20.9 | 20.7 | 20.7 | 21.6 | 13.3 | 16.8 | 409.7 |
| (ESTIMATED CIVIL SERVICE FTEs) | (544) | (50) | (128) | (31) | (2) | (2) | (2) | (2) | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 36.0 | 3.6 | 9.9 | 2.5 | 0.2 | 0.2 | 0.2 | 0.2 | | |

## 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 FY 1998 budget proposes multi-year appropriations for development of TDRS. This will ensure the stability to manage and execute this program within its budget and schedule commitments.

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 for the program within the Space Communications section.

(Budget Authority in Millions of Dollars)

| | PRIOR | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| SPACECRAFT DEVELOPMENT AND GROUND TERMINAL MODIFICATIONS | 47.6 | 147.2 | 162.1 | 107.0 | 69.3 | 37.8 | 19.8 | 16.4 | 19.9 | 627.1 |
| LAUNCH SERVICES | 2.0 | 3.2 | 17.9 | 50.5 | 51.1 | 20.2 | 50.2 | 81.8 | 32.7 | 309.6 |
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | 49.6 | 150.4 | 180.0 | 157.5 | 120.4 | 58.0 | 70.0 | 98.2 | 52.6 | 936.7 |
| (ESTIMATED CIVIL SERVICE FTEs) | (29) | (36) | (42) | (48) | (52) | (37) | (37) | (37) | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | 1.8 | 2.6 | 3.2 | 3.9 | 4.1 | 3.0 | 3.1 | 3.2 | | |

## 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 National Space Transportation Policy directed the **X-33** program to include two major decision points. The first decision, whether to proceed with the demonstration phase (Phase II), was made in July 1996 based on specific programmatic, business planning and technical'criteria which had previously been agreed upon by **NASA,** the Office of Management and Budget and the Office of Science and Technology Policy. With Administration approval, Lockheed Martin Skunkworks, Palmdale, CA was chosen as the **X-33** industry partner. **X-33** flight tests are expected to begin in March, 1999. The second decision will be made at the end of the decade, after **X-33** ground and flight tests, when Government and industry will consider whether private financing of the full-scale development of an operational RLV (Phase III) should be pursued.

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** which offer the most effectivemeans 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 lndustry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs and increased management efficiency. The FY 1998 budget proposes multi-year appropriations for development of the **X-33.** The initiative will ensure the stability to manage and execute this program within its budget and schedule commitments.

As directed by Congress, the **X-33** program funding includes **$10.5** million in Construction of Facilities funding and **$35.0** million in equipment funds in FY 1996 for completion of the Component Test Facility at Stennis Space Center. The **X-33** program also funds refurbishment of the B-2 test stand at Stennis in FY 1997 **($2.3** million) and FY 1998 **($3.7** million) to enable testing of **X-33** and development and flight 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 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Balance | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL EXCLUDING CIVIL SERVICE COSTS ($M) | | 157.5 | 246.8 | 333.5 | 313.9 | 75.0 | | | | 1126.7 |
| (ESTIMATED CIVIL SERVICE FTEs) | | (59) | (240) | (277) | (273) | (65) | | | | |
| CIVIL SERVICE COMPENSATION ESTIMATE ($M) | | 5.1 | 30.8 | 32.4 | 40.7 | 10.0 | | | | |

Human
Space Flight

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

HUMAN **SPACE FLIGHT**

**FISCAL YEAR 1998 ESTIMATES**

## GENERAL STATEMENT

### GOAL STATEMENT

The Human Space Flight program is integral to the NASA enterprise for the Human Exploration and Development of Space (HEDS), 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 to develop and operate habitable space facilities, in order to enhance scientific knowledge, support technology development, and enable commercial activity. The four major goals of the Human Space Flight program are the following:

- Increase human knowledge of nature's processes using the space environment
- Explore and settle the solar system
- Achieve routine space travel
- Enrich life on Earth through people living and working in space

### STRATEGY FOR ACHIEVING GOALS

In Human Space Flight, we are committed to ensuring effective, efficient and safe transportation to and from space, while continually seeking to improve the safety margin of the Space Shuttle. We are actively probing our process 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 will transition from Spacelab to the conduct of joint space activities with Russia at Mir, assemble International Space Station, and then accomplish the development, operation, and utilization of the International Space Station.

Human Space Flight, through the utilization of Space Shuttle, Spacelab and Space Station, provides the capabilities to enable the development of advanced space systems, technologies, and materials. 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 derived from past space activities. we will continue to emphasize Human Space Flight's contribution to the national community. These contributions will be implemented by contributing to science and engineering

educational opportunities for our youth, by enhancing U.S. competitiveness in the world and in space though 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 customer needs along with pressure 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 to future technological advances for humans as they further expand their presence in space.

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

HUMAN **SPACE FLIGHT**

**FISCAL YEAR 1998 ESTIMATES**
**(IN MILLIONS OF REAL YEAR DOLLARS)**

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| HUMAN **SPACE FLIGHT** | **5,710.4** | **5,674.8** | **5,326.5** |
| SPACE STATION | 2,143.6 | 2,148.6 | 2,121.3 |
| US/RUSSIAN COOPERATION | 100.0 | 100.0 | -- |
| SPACE SHUTTLE | 3,143.8 | 3,150.9 | 2,977.8 |
| PAYLOAD AND UTILIZATION OPERATIONS | 323.0 | 275.3 | 227.4 |

## 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. 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. [$5,362,900,000] $5,326,500,000, to remain available until September 30. [1998] 1999.

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 1998, $2,121,300,000; for fiscal year 1999, $2,109,200,000; for fiscal year 2000, $1,914,600,000; for fiscal year 2001, $1,596,800,000; and for fiscal year 2002. $1.1 47.000.000. (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act. 1997.1

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## HUMAN SPACE FLIGHT

### REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| HUMAN SPACE FLIGHT | **69.6** | **82.0** | **70.6** |
| SPACE STATION | 0.1 | -- | -- |
| US/RUSSIAN COOPERATION | -- | -- | -- |
| SPACE SHUTTLE | 35.1 | 36.3 | 25.6 |
| PAYLOAD AND UTILIZATION OPERATIONS | 34.4 | 45.7 | 45.0 |

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## FISCAL YEAR 1998 ESTIMATES
## SUMMARY OF RESOURCES REQUIREMENTS

## DISTRIBUTION OF HUMANS SPACE FLIGHT BY INSTALLATION
## (IN THOUSANDS OF REAL YEAR 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 | Lewis Research Center | Goddard Space Flight Center | Jet Propulsion Lab | Head-quarters |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Station | 1996 | 2,143,600 | 1,871,429 | 50,049 | 118,484 | 0 | 26,296 | 0 | 4,867 | 44,136 | 765 | 2,400 | 25,174 |
| | 1997 | 2,148,600 | 1,927,300 | 71,000 | 92,800 | 0 | 19,900 | 0 | 9,000 | 18,100 | 100 | 200 | 10,200 |
| | 1998 | 2,121,300 | 1,806,200 | 91,600 | 151,200 | 0 | 27,300 | 0 | 4,400 | 26,600 | 0 | 2,800 | 11,200 |
| U.S.-Russian Cooperative Program | 1996 | 100,000 | 99,200 | 800 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1997 | 100,000 | 100,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Space Shuttle | 1996 | 3,143,800 | 1,006,300 | 795,800 | 1,265,900 | 51,700 | 0 | 5,600 | 0 | 0 | 100 | 200 | 18,200 |
| | 1997 | 3,150,900 | 976,300 | 777,600 | 1,330,100 | 40,500 | 0 | 5,400 | 0 | 0 | 0 | 0 | 21,000 |
| | 1998 | 2,977,800 | 1,061,100 | 753,800 | 1,101,900 | 33,900 | 0 | 5,900 | 0 | 0 | 0 | 0 | 21,200 |
| Payload and Utilization Operations | 1996 | 323,000 | 96,400 | 88,600 | 118,300 | 1,600 | 0 | 0 | 300 | 0 | 9,500 | 0 | 8,300 |
| | 1997 | 275,300 | 90,700 | 72,500 | 96,300 | 1,700 | 0 | 0 | 300 | 0 | 7,300 | 0 | 6,500 |
| | 1998 | 227,400 | 98,700 | 58,900 | 53,800 | 1,400 | 0 | 0 | 500 | 0 | 7,600 | 0 | 6,500 |
| TOTAL HUMAN SPACE FLIGHT | 1996 | 5,710,400 | 3,073,329 | 935,249 | 1,502,684 | 53,300 | 26,296 | 5,600 | 5,167 | 44,136 | 10,365 | 2,600 | 51,674 |
| | 1997 | 5,674,800 | 3,094,300 | 921,100 | 1,519,200 | 42,200 | 19,900 | 5,400 | 9,300 | 18,100 | 7,400 | 200 | 37,700 |
| | 1998 | 5,326,500 | 2,966,000 | 904,300 | 1,306,900 | 35,300 | 27,300 | 5,900 | 4,900 | 26,600 | 7,600 | 2,800 | 38,900 |

Space Station

HUMAN SPACE FLIGHT

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

**OFFICE OF SPACE FLIGHT** **SPACE STATION**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Development | 1,746,200 | 1,766,300 | 1,386,100 | HSF 1-5 |
| Operations | 120,000 | 177,600 | 490,100 | HSF 1-16 |
| Research | 277,400 | 204,700 | 245,100 | HSF 1-21 |
| Total | 2,143,600 | 2,148.600 | 2.121,300 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | 1,871,429 | 1,927,300 | 1,806,200 | |
| Kennedy Space Center | 50,049 | 71,000 | 91,600 | |
| Marshall Space Flight Center | 118,484 | 92,800 | 151,200 | |
| Ames Research Center | 26,296 | 19,900 | 27,300 | |
| Langley'Research Center | 4,867 | 9,000 | 4,400 | |
| Lewis Research Center | 44,136 | 18,100 | 26,600 | |
| Goddard Space Flight Center | 765 | 100 | -- | |
| Jet Propulsion Laboratory | 2,400 | 200 | 2,800 | |
| Headquarters | 25,174 | 10,200 | 11,200 | |
| Total | 2,143,600 | 2,148,600 | 2,121,300 | |

**PROGRAM GOALS**

The goal of the International Space Station is to provide a long-duration laboratory to allow investigation of the limits of human performance, vastly expand human experience in living and working in space, and provide the capability to understand whether

there are additional opportunities for the large-scale commercial development of space. The experience and dramatic results obtained from the use of the International Space Station, together with information obtained from robotic missions to the Moon, near-Earth asteroids, and Mars, will guide the future direction of the Human Exploration and Development of Space Enterprise, one of NASA's key strategic areas. The Space Station is key 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 Space Station is unique because it will provide the world with a permanent international outpost in space. The schedule for the current design emphasizes an early permanent crew capability that provides an advanced research laboratory for use by international crews for extended durations. Therefore, early into 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 International Space Station (ISS) is the culmination of the redesign work begun in FY 1993 to increase efficiency and effectiveness in response to lower projections for the Agency budget and growing emphasis on other programs. Human presence in space is one of NASA's highest priorities, and the redesigned Space Station has met the President's goal to reduce program costs while still providing significant research capabilities. A new management approach was implemented, in which a single contractor (Boeing) was given total prime and integration responsibilities, with the previous prime contractors (McDonnell Douglas, Rocketdyne, and Boeing Huntsville) serving as first-tier subcontractors to Boeing. This produced clearer lines of authority and greater accountability. In addition, program management relocated to a Space Station Program Office (SSPO) in Houston, structured around integrated product teams with responsibility for bringing the systems and elements into integrated launch packages.

The Space Station program operates within an annual funding constraint of $2.1 billion, with a total budget cap of $17.4 billion at Assembly Complete in June 2002. The baseline program content includes development and operations, Space Shuttle-Mir activities, science payload facilities, and utilization related to the Space Station. Extensive coordination with the user community is ongoing, with payload facilities development and research and technology activities coordinated with the Office of Life and Microgravity Sciences and Applications (OLMSA), and the Office of Mission to Planet Earth (OMTPE).

This past year 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 annual $2.1 billion budget. The Space Station program manager is now responsible for the cost, schedule and technical performance of the total program. The OLMSA and OMTPE remain responsible for establishing the research requirements to be accommodated on the Space Station and will respond to the direction of the program manager to ensure the utilization priorities and requirements are consistent with the overall Space Station objectives. The FY 1998 budget reflects that consolidation by funding the total annual $2.1 billion budget within the Space Station budget line of the Human Space Flight appropriation account. The research and technology elements of the program, including Mir research and support, and the

station-related space product development activities from the former Office of Space Access and Technology, are included in the Space Station Research funding.

The FY 1998 budget also proposes appropriation language to support multi-year funding to help enable the program to be completed as promised, within budget, and on schedule. The budget proposes $2.1 billion for FY 1998 $2.1 billion for FY 1999, $1.9 billion for FY 2000, $1.6 billion for FY 2001 and $1.1 billion for the first 9 months of FY 2002 in order to achieve completion of **U.S.** assembly in June 2002.

The Space Station's international aspect was initiated in 1984 with invitations for the full participation of other nations. President Clinton expanded the international scope of the Space Station dramatically by forming a cooperation with the Russian Space Agency (RSA). Space Station team members now include NASA, RSA, the Canadian Space Agency (CSA), the European Space Agency (ESA), and the National Space Development Agency of Japan (NASDA). The continued partnerships with the CSA. ESA, and NASDA significantly enhance the capabilities of the International Space Station, and ensure compatible development of interfacing elements. Through FY 1996, the CSA, ESA and NASDA have invested nearly $6 billion for design and development, and anticipate a total expenditure **of** $10 billion. In accordance with the terms of the agreements, the **U.S.** and our international partners will share the total available resources and the common costs for operations. The International Space Station represents an unprecedented level of international cooperation and complexity.

Development of the Space Station program is laid out in three phases. Phase I, which is currently underway, includes nine Shuttle-Mir docking missions. The goals of the Phase **I** are to develop and demonstrate joint mission procedures with Russia, to gain valuable experience to reduce technical risk during International Space Station construction, and to provide early opportunities for extended scientific research.

Phase II begins with the launch of the U.S.-owned/Russian-launched functional cargo block (FGB) in November 1997. Permanent crew capability for three persons will be available upon delivery of the **Soyuz** in May 1998. Microgravity capability will be available in January 1999, with the outfitting of the **U.S.** laboratory. At this stage, the Station configuration will include the **U.S.** node, laboratory, pressurized mating adapters, power, airlock and mini-pressurized logistics module (MPLM); Russian FGB, docking compartment and crew return; and the Space Station remote manipulator system **(SSRMS),** provided by Canada.

Phase III will begin in June 1999. Integration of the international modules, including the Japanese Experimental Module (JEM), European Columbus Orbital Facility (COF), Russian research modules, plus the U.S. habitation module in April 2002 will complete the pressurized volume space and crew accommodations. Delivery of the crew rescue vehicle and the final outfitting flight will mark assembly complete of the International Space Station, and permanent 7-member crew capability. At the completion of this phase, the configuration will include a second **U.S.** node, habitation module, cupola, truss elements and solar arrays; international laboratory and research modules, docking and life support modules, solar arrays and resupply/support vehicles. The centrifuge and the European COF will be launched after permanent 7-member crew capability is achieved.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE STATION DEVELOPMENT

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Flight hardware | 1,468,900 | 1,480,500 | 1,157,900 |
| Test, manufacturing and assembly | 73,500 | 97,300 | 93,600 |
| Operations capability and construction | 112,600 | 130,700 | 85,400 |
| Transportation support | 63,500 | 55,700 | 47,800 |
| Flight technology demonstrations | 12,900 | 2,100 | 1.400 |
| Subtotal | 1,731,400 | 1,766,300 | 1,386,100 |
| Operations capability and construction | | | |
| Neutral buoyancy laboratory - CofF | 14,800 | -- | -- |
| Total | 1,746,200 | 1,766,300 | 1,386,100 |

## PROGRAM GOALS

Development of the International Space Station will provide an on-orbit, habitable laboratoxy for science and research activities, including flight and test hardware and software, flight demonstrations for risk mitigation, ground operations capability and 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

Space Station elements will be provided by the U.S. and our international partners. The U.S. elements include two nodes, a laboratory module, 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. elements also include the FGB energy tug, being provided by a Russian firm under the Boeing prime contract, and pressurized logistics modules, similarly provided by Italy.

Canada, European nations, Japan, and Russia are also developing hardware for the International Space Station. Laboratory elements will be provided by the Japanese and European Space Agencies. Canada will provide the remote manipulator system,

vital for assembly of the station. The Russian Space Agency is providing experiment, power, life support and service modules, Soyuz crew transfer vehicle, and universal docking modules.

Boeing is the prime contractor for the Space Station, with responsibility for integration and assembly of the International Space Station. As a subcontractor to Boeing, McDonnell Douglas is developing and building the integrated truss segments that separate station elements and house essential systems, including central power distribution, thermal distribution and attitude control equipment. Radiators, communications antennas, photovoltaic (PV) elements and the Space Station robotics manipulator system are also mounted to truss segments. Additionally, McDonnell Douglas provides major components of the communications and data handling, thermal control, and the guidance, navigation and control subsystems.

U.S. pressurized volumes are being developed by Boeing Defense and Space Group, Missiles and Space Division in Huntsville, which is considered a first tier subcontractor to Boeing prime. After the first element launch of the FGB energy block in November 1997, the next flight will launch node 1, a pressurized volume which contains four radial and two axial berthing ports. The node will be launched with two pressurized mating adapters (PMAs) attached and will serve as the docking location for the delivery of the U.S. laboratory module and the pressurized logistics module. Node 2, with an attached cupola, is currently manifested for flight during March 2000. The final U.S. pressurized volume is the habitation module which will contain the galley, wardroom, waste management, water processing and other crew support functions necessary for human operations.

The power system, essential to the Station's housekeeping operations and scientific payloads, is being built by Rocketdyne Division, Rockwell International, in a subcontracted effort to Boeing. Four photovoltaic elements, containing a mast, rotary joint, radiator, arrays and associated power storage and conditioning elements make up the power system.

The development 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, communications and tracking, and 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.

Operations capability provides for the development of a set of facilities, systems and capabilities to conduct the operations of the Space Station. The work will be performed at the Kennedy Space Center (KSC) and the Johnson Space Center (JSC). The KSC will develop launch site operations capabilities for conducting pre-launch and post-landing ground operations. The JSC will develop space systems operation capabilities for conducting training and on-orbit operations control of the Space Station. Construction of the neutral buoyancy laboratory (NBL) in Houston will provide the capability for Space Station crew training to support a March 1997 training need date. Requirements for simultaneous extravehicular activity (EVA) training (up to nine crews at a time) and larger volume for time critical EVA tasks has dictated the NBL requirement.

The redesigned Space Station emphasizes multicenter and multiprogram cooperation. At JSC, a consolidated approach between Space Shuttle and Space Station minimizes duplicated effort and costs for command and control and training. Crew training will

be based on a detailed risk analysis to determine the optimum failure response training profile. Therefore, training will be knowledge- and proficiency-based rather than driven by timeline and detailed procedures rehearsal.

Transportation support provides those activities which are required to mate and integrate the Space Shuttle and Space Station systems. This budget line supports development and procurement of two external airlocks, and upgrade of a third airlock to full system capability, which are required both for docking the Space Shuttle with the Russian Mir and for use with the Space Station. Other items in this budget include: the 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.

Space Station technology and system validation funding requirements include flight technology demonstrations, flown during Phase I, in areas of joint NASA/RSA development that pose a level of technical or programmatic risk warranting additional verification. Risk areas include life support, the data processing system, automatic rendezvous and docking, vibration isolation in a microgravity environment, assembly and maintenance, loads and dynamics, contamination, radiation environment, and micrometeoroid/orbital debris. In addition, funding is provided for operational techniques development for procedures, utilizing the Space Shuttle flights to the current Russian Mir, that will benefit the future operational phases of the Space Station program. A change in the logistics requirements for Mir caused a flight cancellation of the solar dynamic technology demonstration payload that was being developed jointly with RSA, and which was co-funded with the Office of Space Access and Technology.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Completed Incremental Design Review<br>Perform IDR #2 March 1996<br>Perform IDR #3 March 1997 | 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 through 6A. Subsequently, IDR#2 was conducted during March 1996 to assess design progress for flights 1A through 7A. IDR#2B (September 1996) assessed the entire Space Station assembly sequence. |
| Perform Stage Integration Reviews for flights through UF1, FY 1997 Perform Stage Integration Review for flights through 5R, FY 1998 | IDRs have been replaced by a more classical CDR approach on a stage-by-stage basis, which review groupings of flights with assembly hardware and functionality/performance linkages across the stage. |

| Prime Development Activity | NOTE: All activities listed are planning milestones, and are not contractual. |
|---|---|
| Flight 1A/R: (November 1997)<br>FGB Energy Block<br>(First Element Launch)<br>(Proton Launch Vehicle) | 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.<br><br>• Completed solar array compartment test on test article (2nd Qtr FY 1996)<br>• Completed manufacture of structural components for first FGB flight (3rd Qtr FY 1996)<br>• Completed subcontractor component deliveries to RSA for FGB assembly (3rd Qtr FY 1996)<br>• Completed manufacture of compartment that houses solar arrays on FGB (2nd Qtr FY 1996)<br>• Completed manufacture of the second of two solar panels for the FGB (3rd Qtr FY 1996)<br>• Complete flight software (slip from 1st Qtr FY 1997 to 3rd Qtr FY 1997)<br>• Deliver FGB flight article to Baikanour (3rd Qtr FY 1997)<br>• Complete factory ground testing of first flight unit (3rd Qtr FY 1997)<br>• Install solar arrays in FGB flight article (1st Qtr FY 1998)<br>• Mating of FGB to Launch Vehicle (1st Qtr FY 1998)<br>• Launch (1st Qtr FY 1998)<br>• On-Orbit checkout, Service Module docking, fuel transfer (1st Qtr FY 1998) |
| Flight 2A: (December 1997)<br>Node 1, Pressurized Mating Adapters (PMA-1, PMA-2) | 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.<br><br>• Completed mechanical equipment installation into node structural test article (STA) (2nd Qtr FY 1996)<br>• Complete Node STA proof pressure/leak rate qualification testing (slip from 4th Qtr FY 1996 to 1st Qtr FY 1997<br>• Begin Engineering, fabrication, assembly, set-up and preparation for node STA modal survey test (Slip from 3rd Qtr FY 1996 to 1st Qtr FY 1997)<br>• Complete installation of mechanical equipment into Node 1 flight article primary structure (Slip from 3rd Qtr FY 1996 to 1st Qtr FY 1997)<br>• Complete design and fabrication of Node 1 flight article external secondaxy structure (Slip from 3rd Qtr FY 1996 to 2nd Qtr FY 1997)<br>• Begin final assembly and outfitting of all major components of Node 1 flight article (Slip from 4th Qtr FY 1996 to 1st Qtr FY 1997)<br>• Complete pressurized mating adapter (PMA-1) shell (1st Qtr FY 1997)<br>• Completed mechanical equipment installation into node structural test article (STA) (2nd |

Qtr FY 1996)

- Complete Node STA proof pressure/leak rate qualification testing (slip from 4th Qtr FY 1996 to 1st Qtr FY 1997
- Begin Engineering, fabrication, assembly, set-up and preparation for node STA modal survey test (Slip from 3rd Qtr FY 1996 to 1st Qtr FY 1997)
- Complete installation of mechanical equipment into Node 1 flight article primary structure (Slip from 3rd Qtr FY 1996 to 1st Qtr FY 1997)
- Complete design and fabrication of Node 1 flight article external secondary structure (Slip from 3rd Qtr FY 1996 to 2nd Qtr FY 1997)
- Begin final assembly and outfitting of all major components of Node 1 flight article (Slip from 4th Qtr FY 1996 to 1st Qtr FY 1997)
- Complete pressurized mating adapter (PMA-1) shell (1st Qtr FY 1997)
- Complete STS-88 Cargo Integration Review (1st Qtr FY 1997)
- Complete PMA-2 shell (Slip from 4th Qtr FY 1996 to 2nd Qtr FY 1997)
- Begin PMA-1 & 2 acceptance test (2nd Qtr FY 1997)
- Stage Integration Review #1 (2nd Qtr FY 1997)
- PMA 1 & 2 on dock at KSC (3rd Qtr FY 1997)
- Complete Node 1 acceptance test (3rd Qtr FY 1997)
- Node 1 on dock at KSC (3rd Qtr FY 1997)
- Complete Node STA static flight loads testing (4th Qtr FY 1997)
- Complete Flight 2A Cargo Element Integration and Test (1st Qtr FY 1998)
- Space Shuttle Payload Integration and Test (1st Qtr FY 1998)
- STS-88 Launch (1st Qtr FY 1998)

Flight 3A: (July 1998)
Z1 Truss Segment, Control Moment Gyros (CMGs), PMA-3, KU-Band

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.

- Began Z1 truss Critical Design Review (2nd Qtr FY 1996)
- Began fabrication and assembly of Z1 truss (2nd Qtr FY 1996)
- Completed design of CMGs (1st Qtr FY 1996)
- Began build of CMG flight articles 1-4 (2nd Qtr FY 1996)
- PMA-3 pressurized shell & secondary structure on-dock at McDonnell Douglas for tooling & fabrication (2nd Qtr FY 1996)
- Begin fabrication of 3A Flight Model DDCUs (1st Qtr FY 1997)
- Complete fabrication and assembly of CMG qualification unit (Slip from 3rd Qtr FY 1996 to 2nd Qtr FY 1997)

- Z1 fabrication and assembly complete (2nd Qtr FY 1997)
- Complete flight article CMG acceptance test for flight unit #1 (2nd Qtr FY 1997)
- Complete Z1 Truss Critical Design Review (2nd Qtr FY 1997)
- Z1 modal and static qualification tests complete (4th Qtr FY 1997)
- PMA-3 on-dock at KSC (Slip from 3rd Qtr FY 1997 to 4th Qtr FY 1997)
- KU-Band on dock at KSC (2nd Qtr FY 1998)
- S-Band on dock at KSC (2nd Qtr FY 1998)

Flight 4A: (November 1998) P6 Truss segment, Photovoltaic Array, Thermal Control System (TCS) Radiators, S-Band Equipment

Establishes initial U.S. photovoltaic module based power capability: installed in a temporary location on top of the Z1 truss until flight 13A when it is permanently attached to the P5 truss: includes 2 TCS radiators for early active thermal control.

- Completed P6 long spacer qualification unit design (2nd Qtr FY 1996)
- Completed Flight PVR final assembly and began acceptance testing (4th Qtr FY 1996)
- Completed EEATCS delta CDR (4th Qtr FY 1996)
- Complete mechanical installation and outfitting of IEA qualification unit (Slip from 4th Qtr FY 1996 to 1st Qtr FY 1997)
- Complete deploy and retraction testing on PV arrays pre-flight qual Unit (1st Qtr FY 1997)
- Complete E-wing life cycle testing (1st Qtr FY 1997)
- Complete assembly of P6 integrated electronics assembly (IEA) qualification unit (1st Qtr FY 1997)
- Complete IEA qualification unit hardware/software integration and functional testing (1st Qtr FY 1997)
- Begin thermal balance testing of IEA qualification unit (2nd Qtr FY 1997)
- Begin P-6 long spacer flight hardware fabrication/assembly (1st Qtr FY 1997)
- Complete fabrication and assembly of P6 long spacer qualification unit (3rd Qtr FY 1997)
- Complete IEA flight unit fabrication (3rd Qtr FY 1997)
- P6 long spacer on dock at KSC (2nd Qtr FY 1998)
- IEA to KSC (2nd Qtr FY 1998)
- Complete flight qualification IEA testing (3rd Qtr FY 1998)
- PV Arrays flight units on dock at KSC (3rd Qtr FY 1998)

| | |
|---|---|
| Flight 5A: (December 1998)<br>U.S. Laboratory,<br>5 Lab System Racks | Establishes initial U.S. user capability: launches with 4 system racks preintegrated: KU-band and CMGs are activated.<br><br>• Begin laboratory common module STA qualification testing (Slip from 4th Qtr FY 1996 to 1st Qtr FY 1997)<br>• Complete development of lab flight article pressure vessel (Slip from 4th Qtr FY 1996 to 2nd Qtr FY 1997)<br>• Standoff endcones - Design completed (Slip from 4th Qtr FY 1996 to 2nd Qtr FY 1997)<br>• Complete Mission Integration Plan Baseline (2nd Qtr FY 1997)<br>• Complete Flight 5A Stage Integration Review (4th Qtr FY 1997)<br>• Complete lab racks, crew systems, closeouts, and hatch installation (1st Qtr FY 1998)<br>• Complete Cargo Integration Review (1st Qtr FY 1998)<br>• Complete Lab qualification testing (hardware/software integration) (3rd Qtr FY 1998)<br>• Lab on dock at KSC (4th Qtr FY 1998) |
| Flight 6A: (January 1999)<br>Mini-Pressurized Logistics Module, Canadian Remote Manipulator System, UHF | Adds U.S. lab outfitting with 1 stowage and 7 systems racks: UHF antenna provides space-to-space communication capability for U.S. based EVA manifests Canadian SSRMS needed to perform assembly operations on later flights.<br><br>• Completed fabrication of MPLM-1 qualification unit (3rd Qtr FY 1996)<br>• Begin fabrication and assembly of MPLM-1 flight article (3rd Qtr FY 1996)<br>• Deliver SSRMS Structural Test Article to NASA (2nd Qtr FY 1997)<br>• Baseline Flight 6A Mission Integration Plan (2nd Qtr FY 1997)<br>• Complete MPLP System Critical Design Review (2nd Qtr FY 1997)<br>• Complete MPLM FM 1 structure manufacturing and assembly (3rd Qtr FY 1997)<br>• Complete Stage Assessment Review (4th Qtr FY 1997)<br>• Complete Stage Assessment Integration Review (4th Qtr FY 1997)<br>• Cargo Integration Review (2nd Qtr FY 1998)<br>• Begin integration of Spacelab Logistics Pallet Cargo Element (2nd Qtr FY 1998)<br>• Deliver MPLM to KSC (3rd Qtr FY 1998)<br>• Deliver Lab Racks to KSC (4th Qtr FY 1998)<br>• Complete Flight Operations Review (4th Qtr FY 1998) |

**Non-Prime Development Activity**

| | |
|---|---|
| Global Positioning System | Provides autonomous, real-time determination of Space Station's position, velocity, and attitude of absolute time<br>• Complete Critical Design Review (4th Qtr FY 1996)<br>• Deliver GPS Receiver/Processor (3rd Qtr FY 1997)<br>• Deliver GPS Antenna Assembly (2nd Qtr FY 1998) |
| Extra-Vehicular Activity System | • Provides GFE EVA unique tools, Orlan SAFER (Russian space suit), 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.<br>• Deliver Crew Equipment Transfer Aid Cart Proto-Flight unit (1st Qtr FY 1997)<br>• Deliver Bi-Lateral Tools for Testing (2nd Qtr FY 1997)<br>• Deliver Articulating Portable Foot Restraints (3rd Qtr FY 1997)<br>• Deliver Orbital Support Equipment (3rd Qtr FY 1997)<br>• Deliver Torque Multiplier (3rd Qtr FY 1997)<br>• Deliver Orlan SAFER - first 2 units (1st Qtr FY 1998)<br>• Deliver Temporary Equipment Restraint Aid (2nd Qtr FY 1998) |
| Crew Health Care System | Provides crew health care system hardware included in the health maintenance system, and the countermeasure system required to ensure crew health and safety.<br><br>This activity and measures of performance have been transferred to Space Station Research. |
| 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 and diagnostic equipment and portable illumination kit.<br>• Complete Critical Design Review (tools/diagnostics/housekeeping (4th Qtr FY 1996)<br>• Complete 6A Operations and Personal Equipment CDR (1st Qtr FY 1997)<br>• Complete Stowage Tray Restraint CDR (2nd Qtr FY 1997)<br>• Complete production of tools and diagnostic flight hardware kit (1st Qtr FY 1998)<br>• Complete CDR for portable illumination (1st Qtr FY 1998)<br>• Complete Personal Hygiene Kit PRR (3rd Qtr FY 1998)<br>• Deliver Maintenance Workstation Kit, Tools and Diagnostic Kit, Portable Illumination, Restraints and Mobility Aids, 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.<br>• Completed Critical Design Review (4th Qtr FY 1996)<br>• Certification unit hardware delivered to Airlock Test Article (Slip from 2nd Qtr FY 1996 to 2nd Qtr FY 1997)<br>• Complete certification unit integration test (4th Qtr FY 1997)<br>• Complete flight unit acceptance test (4th Qtr FY 1997) |
| Station Training Facility | Primary facility for space systems operations training and procedures verification.<br>• Part task trainer ready for Flight 1A (4th Qtr FY 1996)<br>• Achieved Mission Control Center (MCC)/STF integrated operations capability (3rd Qtr FY 1996)<br>• Training capability to support flight 2A (3rd Qtr FY 1997)<br>• Ready For Training (RFT) for flight 5A (4th Qtr FY 1998) |
| Integrated Planning System | Provides planning and analysis tools for pre-increment and real-time operations systems (IPS) supporting trajectory/flight design, timelines, resource utilization, onboard systems, performance analyses systems operation data file procedures and control, maintenance operations, inventory and logistics planning, robotics analysis, procedures development.<br>• Achieved first element launch capability (2nd Qtr FY 1996)<br>• Delivery to support Flight 5A planning and operations (3rd Qtr FY 1997)<br>• Delivery to support Flight 1J/A (2nd Qtr FY 1998) |
| Mission Control Center | Facility providing integrated command and control capabilities and support to real-time increment operations.<br>• Achieved capability for: ascent/entry; full Mir command/telemetry support: data record/playback; initial voice record/playback (3rd Qtr FY 1996)<br>• SVF integration test for flights 2A-4A (2nd Qtr FY 1997)<br>• Delivery to support Flight 2A flight following capability (3rd Qtr FY 1997)<br>• Delivery to support CSA Interface and Payload Interface (3rd Qtr FY 1998)<br>• Delivery to support Flight 5A ISS Command and Control Capability (4th Qtr FY 1998) |
| Neutral Buoyancy Laboratory (NBL) | Provides training tank facility for neutral buoyancy training capability at the Sonny Carter Training Facility.<br>• Complete training tank construction (3rd Qtr FY 1996) |

## ACCOMPLISHMENTS AND PLANS

FY 1996 continued qualification testing, and the manufacturing of flight hardware as the program readies for First Element Launch (FEL) in November of 1997. The Incremental Design Review (IDR) #2A (March 1996) performed a Critical Design Review (CDR) for flights 1A through 7A. IDR #2B (September 1996) assessed the entire assembly sequence. International efforts continued with closure of the NASA/RSA Memorandum of Understanding (MOU) on Space Station and renegotiation of MOUs with ESA, Japan, and Canada to reflect Russian participation. The ESA Ministerial Council met to finalize ESA participation in Station and all partners continue development of flight hardware. The Columbus orbital facility (COF) will reach PDR, the Japanese experimental module (JEM) will undergo CDR # 1 and the Space Station remote manipulator system (SSRMS) will finish final integration.

Power system testing was conducted throughout FY 1996, including the battery charge/discharge unit (BCDU). Type II remote power connectors (RPC), main bus switching unit (MBSU), direct current switching unit (DCSU), external and internal DC-to-DC converter units, and the pump and flow control subassembly (PFCS). The integrated electronics assembly (IEA) qualification unit hardware/software integration and functional testing was completed (1st Qtr FY 1997).

The joint airlock CDR was completed early in the year, followed by welding and mechanical installation. The Z1 truss began CDR fabrication and assembly. Flight hardware production began on all three pressurized mating adapters and the S0 truss segment, in addition to the truss segment S1 structural test article (STA). The Pressurized Mating Adapter-2 (PMA-2) weld qualification test was completed along with hatch and antenna qualification testing. Final assembly and outfitting of all major components of the node 1 flight article will begin, as well as the common module structural test article. Control moment *gyros* (CMGs) qualification unit build was completed and night article builds will commence.

During FY 1997 the major program focus will be manufacturing and testing flight hardware to support FEL in November of 1997 and subsequent launches throughout 1998. Major preparation will be made in support of the FGB, node 1, truss segments, the U.S. laboratory, and the subsystems to support these elements. The international partners will continue development of flight hardware with the FGB flight article assembly completion and delivery to Baikanour, the start of the SSRMS performance test, and the JEM CDR 2.

U. S. efforts include the node STA qualification test completion, the node 1 acceptance test completion and delivery of the node 1 to KSC the third quarter of FY 1997. Control moment *gyros* (CMGs) qualification test, Z1 truss static test, control and data handling (C&DH) formal stage test, and integrated electronics assembly (IEA) acoustic tests will also be performed.

Integration of node 1 and PMA 1 and 2 will occur during FY 1997. The Z1 truss fabrication and assembly, CMG flight article fabrication and the Integrated Electronics Assembly (IEA) structural framework fabrication are to be completed before the end of fiscal year 1997. The Mini-Pressurized Logistics Module (MPLM) will undergo CDR and the primary structure will be manufactured and assembled. Installation of lab endcone hardware, racks and hatches will begin.

FY 1998 will see Phase 2/3 assembly of the International Space Station begin with the launch of the U.S. owned/Russian launched Functional Cargo Block (FGB). The FGB is a self sufficient orbital vehicle that will provide initial capabilities for propulsion, guidance, communication, electrical power and thermal control systems.

Launch of Node # 1 (1 stowage rack), PMA 1 & PMA 2 by the Space Shuttle will follow. PMA 1 will provide a pressurized tunnel between the U.S. pressurized elements and the Russian Modules. The PMA 2 will provide a Shuttle docking location.

On flight 1R, the Russian-provided Service Module will contain all the systems necessary for independent orbital operations and serves as a habitat and laboratory. The Service Module launch schedule is under review and contingency options are being addressed. Flight 2R launches a **Soyuz** crew transfer vehicle giving the International Space Station three person human permanent presence capability, and initial science research microgravity capability will follow.

Flight 3A launches the first truss segment 21, the third PMA, Ku-band, control moment gyros, S-Band equipment, and Extravehicular Activity Subsystem (EVAS) components. The Z1 truss segment serves as a temporary location for the first Photovoltaic (PV) assembly (P6).

## BASIS OF FY 1998 FUNDING

### SPACE STATION OPERATIONS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Vehicle operations | 37,500 | 58,500 | 277,500 |
| Ground and transportation operations | 82,500 | 119,100 | 212,600 |
| Total | 120,000 | 177,600 | 490,100 |

### PROGRAM GOALS

The first objective of the operations program is to provide for the safe, reliable, and sustained operation of the Space Station and the ground and transportation operations required to plan, train, and fly the vehicle. The second major goal is to perform the operations in a simplified and affordable manner. Space Station operations will rely on the infrastructure developed for the Space Shuttle, and the experience derived from the Space Shuttle-Mir program to develop efficient and effective operations. Finally, operations will facilitate the transition of the various elements of development to the operations program.

### STRATEGY FOR ACHIEVING GOALS

In order to increase the efficiency and lower the cost of operations, vehicle operations and ground and transportation operations planning began early in development. Streamlining and efficiencies with existing programs will be maximized.

Vehicle operations will provide post-development systems engineering and integration to sustain the specification 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.

Vehicle operations sustaining engineering will be performed by a small cadre of civil service system experts supported by a small number of sustaining engineering contractors. Additionally, flight hardware and software sustaining engineering will be consolidated 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 reduced 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 will provide command and control, training, operations support and launch site processing. A unified command and control center for the Space Station is composed of the Mission Control Center-Houston (MCC-H) and the Mission Control Center-Moscow (MCC-M) at Kaliningrad. 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 the Russian communication assets.

Flight controllers will be trained to operate the Space Station as a single integrated vehicle, with full systems capability in the training environment. Crew members will be trained in Space Station systems, operations, and other activities expected during a mission. Part-task and full hardware mockups and simulators will be 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.

Operations support will provide 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 will provide 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.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Baseline first multi-increment manifest<br>Plan: January **1996**<br>Actual: November **1996** | Multi-increment Manifest delayed due to assembly sequence rebaselining. |
| Baseline sustaining engineering implementation<br>Plan: June **1996**<br>Actual: September **1996** | Details the roles and responsibilities of NASA and the prime contractor for sustaining the International Space Station hardware and software after delivery to NASA. |

| | |
|---|---|
| Demonstrate MCC-H to MCC-M telemetry support capability<br>Plan: July 1996<br>Actual: April 1996 | Development of the Mission Control Center - Houston (MCC-H) to Mission Control Center-Moscow (MCC-M) (demonstrated as part of Phase I flight following activity) telemetry capability necessary for the support of the Space Station flight vehicle. |
| Baseline International Space Station program implementation plan<br>Plan: December 1996<br>Actual: October 1996 | Details the roles, responsibilities, and implementation plans for NASA and its international partners to support International Space Station operations. |
| Publish Preliminary Flight Rules<br>Plan: January 1997 | ISS Generic Flight Rules, Volume B Development of ISS Flight Rules continues with participation by International Partners and Shuttle. |
| Baseline Second Multi-Manifest<br>Plan: April 1997 | Annual update of multi-increment manifest covering Program multi-lateral vehicle traffic and crew rotation plan through Assembly Complete. |
| KSC ground support equipment ready to support Flight 2A<br>Plan: April 1997 | Completion of the design, manufacture, and activation/validation of KSC supplied ground support equipment for Flight 2A will provide a basic processing capability to support all Station hardware flights. |
| Baseline mission integration plan for UF-1<br>Plan: May 1997 | Required to define utilization flight (UF-1) mission requirements and payloads. |
| Complete MCC-H/SSTF integrated operations training capability<br>Plan: May 1997 | Supports the training schedule to train ground crews for real-time operations of the Space Station vehicles. |
| Complete SSPF operational readiness<br>Plan: June 1997 | Completion of the installation and activation of the Space Station Processing Facility (SSPF) and facility systems. Provides the capability to support launch site processing of the KSC launched cargo elements. |
| Demonstrate MCC-H to MCC-M Command Support Capability<br>Plan: August 1997 | Development of the Mission Control Center - Houston (MCC-H) to Mission Control Center - Moscow (MCC-M) command capability re-essay for the support of Space Station Operations. |

| | |
|---|---|
| Begin MCC-H ISS flight following with flight 1 A/R and 2A<br>Plan: November 1997 | 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. |
| Publish MIM 98-1<br>Plan: April 1998 | Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through assembly complete. |
| Publish Operations Summary 98<br>Plan: June 1998 | Annual update to the ISSP Operations Summary, which defines basic ISS resources available for long range utilization planning. |
| Baseline IDRD PP#3<br>Plan: July 1998 | The IDRD includes requirements and resource allocations for Planning Period 3 which covers the 2000 timeframe. |

**ACCOMPLISHMENTS AND PLANS**

In FY 1996, funding supported MCC-M command and telemetry capability development and data/voice record and playback capability. The integrated planning system has initial Station capability to support planning for first element launch. Supply, transportation, and site facilities support infrastructure required for spares and repairs was provided in preparation for major buys that will begin in FY 1997. Additionally, long lead spare items such as electrical, electronic, and electro-mechanical (EEE) parts were purchased to support orbital replaceable unit (ORU) spares. *Also* in FY 1996, the International Space Station program planning established integrated traffic and crew rotation plans for Phase 2 through the development of the multi-increment manifest. Program operational requirements were established through increment definition and requirements documentation (IDRD). Flight products were developed in draft form as part of the normal two-year flight production template flight rules and procedures.

In FY 1997, work will continue on KSC launch site requirements definition, processing plans, and scheduling, as well as the development of ground support equipment and the test control and monitor system (TCMS). The SSPF and facility systems installation, activation, and validation will continue until the operational readiness date, which is set for June 1997. A change will be made to the ISS Prime Contract to add Sustaining Engineering effort through Assembly Complete plus 12 months. Final preparations for the first element launch will be reviewed through the increment integration review for Increment 1. Plans for the first utilization flight will be formally defined through approval of the Shuttle mission integration plan for UF-1. The SSTF and MCC-H will be ready to begin crew and ground controller training for flights 1A-4A. Also during FY 1997, the integrated planning system will be ready to support planning for the 1A-5A flights. The basic mission rules and operations data file for flights 1A-4A will also be produced. In FY 1997 and FY 1998, suppliers and original manufacturers will be put on repair retention contracts to ensure repair of failed equipment and continued operation of ISS. Procurement of spares below the equipment level will be a major thrust in FY 1997.

In FY 1998, the MCC-H will begin functioning in a flight-following mode of operation starting with the first element launch on ISS flight 1A/R, and will continue to operate in this mode throughout FY 1998. The MCC-H is planned to take over the primary real-time command and control of the ISS in early 1999. Updates to the multi-increment manifest and to the definition of ISS resources available for long range utilization planning will continue, and the IDRD for the year 2000 timeframe will be baselined.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE STATION RESEARCH

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Mir research and support | 81,700 | 58,200 | 45,300 |
| Utilization support | 47,400 | 35,100 | 62,300 |
| Research facilities | 128,500 | 80,400 | 102,500 |
| Science utilization | 16,500 | 31,000 | 35,000 |
| Subtotal | 274.100 | 204,700 | 245,100 |
| Science utilization Addition to Microgravity Development Laboratory - CofF | 3,300 | -- | -- |
| Total | 277,400 | 204,700 | 245,100 |

## PROGRAM GOALS

The International Space Station (ISS) will be the world's premier facility for studying the role of gravity on biological, physical and chemical systems. NASA plans to utilize the Space Station as an interactive laboratory in space to advance fundamental scientific knowledge and to contribute new scientific discoveries for the benefit of the United States and to accelerate the rate at which it develops beneficial applications derived from long-term, space-based research. The program will deliver the capability to perform unique, long-duration, microgravity-dependent, space-based research in cell and developmental biology, plant biology, human physiology, biotechnology, fluid physics, combustion science, materials science and fundamental physics. ISS also provides a unique platform for making observations of the Earth's 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 Space Station era, there will be a major transition from the current on-orbit experimentation program to the ISS. The core of the Space Station program will be seven major research facilities: the Gravitational Biology Facility (GBF), the Centrifuge Facility (CF), the Human Research Facility (HRF), the Space Station Furnace Facility (SSFF), the Biotechnology Facility (BTF) (which includes the Protein Crystal Growth activities), Fluids and Combustion Facility (FCF) and the Low Temperature Microgravity Physics Facility (LTMPF). In addition to the seven major facilities, NASA will develop Laboratory Support Equipment and the Expedite the Processing of Experiments to Space Station (EXPRESS) racks and pallets for the Station.

## STRATEGY FOR ACHIEVING GOALS

A number of changes to the Space Station research program have occurred over the past year. 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 annual $2.1 billion budget. The Space Station program manager is now responsible for the cost, schedule and technical performance of the total program. The OLMSA and OMTPE remain responsible for establishing the research requirements consistent with the overall Space Station objectives. The FY 1998 budget reflects that consolidation by funding the total annual $2.1 billion budget within the Space Station budget line of the Human Space Flight appropriation account. The research and technology elements of the program, including Mir research and support, and the station-related space product development activities from the former Office of Space Access and Technology, are included in the Space Station Research funding.

The program has undergone a major restructuring in order to match research utilization of the on-orbit resources with the research support capabilities during the assembly period, and to enhance science planning and training for long-term operations. Current reviews of research facilities, payloads, and user operations against the NASA research objectives will be completed in early spring of 1997 to ensure that the maximum strategic scientific and technological return is achieved. In order to more closely align the delivery of the research facilities to the Station with the availability of crew time, power and upmass capabilities, as well as to address fiscal constraints, several research facilities are now targeted for delivery toward the end of the assembly phase of the Station. In addition, early research on board the Station during the assembly/construction phase is being realigned to the available resources. Rephasing the overall research resulted in the flexibility to transfer $50 million in FY 1996 and $177 million in FY 1997 from research to Space Station development. The funding levels in FY 1999 - FY 2002 will be planned to provide for the priority major research facilities and the associated research infrastructure to be in place at the conclusion of the assembly phase of the Station. As a consequence of the reviews to date, U.S. funding requirements for the Centrifuge Rotor and the Life Sciences Glovebox have been deleted with the assumption that an international partner will agree to assume the responsibility for developing these components in lieu of exchange for other considerations provided by NASA.

### Mir research and support

Mir research and support provides for early research opportunities during Phase 1 by conducting long-duration science aboard the Russian Mir space station, as well as shorter duration science investigations on the Space Shuttle rendezvous missions to Mir. Nine Space Shuttle missions to Mir are planned: four were completed by the end of FY 1996, three are planned for FY 1997, and two in FY 1998. The primary objectives of these flights are to rendezvous and dock with the Mir: perform on-orbit, joint U.S./Russian science and research; perform on-orbit joint operations, which will serve as a platform for future ISS operations: resupply Mir logistics: and rotate the American astronauts on-board Mir. The first of these flights employed a Spacelab long module to support experiment transport and operation, as well as the transport of Mir hardware. The second flight delivered a docking module and solar arrays to Mir. Seven other flights require pressurized habitable modules to transport Russian logistics items, NASA and Russian science and technology payloads, and ISS risk mitigation payloads to Mir. Modules for Flights 3 through 9 are being supplied under a contract with Spacehab, Inc.

The Russian government is making a contribution toward the success of this mission by providing access to their Mir Space Station, providing training for our astronauts, and working with NASA to develop joint operational procedures. By contributing their expertise in long-duration missions gained through many years of Mir operations, and assisting NASA in the development and test of procedures used to rendezvous and dock with the Mir, they are strengthening NASA's ability to assemble safely and efficiently operate and use the ISS. Major contractors involved in the U.S./Russian Cooperative program include the RSA, the RSC-Energia, Krunichev, the Gagarin Cosmonaut Training Center, Rockwell International, Spacehab, Inc., Boeing. Rocketdyne, Allied Signal, and Lockheed Martin.

The Life Science NASA/Mir Research Program (NMRP) will support research investigations in environmental monitoring and countermeasures development and validation aboard the Mir. These investigations will emphasize musculoskeletal, cardiovascular, regulatory physiology. and neuroscience research, along with plant biology and other fundamental biology research. The Biorack facility developed by the European Space Agency (ESA) will fly on three of the Space Shuttle flights to the Mir. The Biorack will be accommodated inside the pressurized Commercial Middeck Accommodations Module (CMAM), owned by SpaceHab, Inc. Biorack researchers will investigate the influence of gravity on cellular functions and developmental processes in plant and animal tissues. NASA will also use Mir to perform flight experiments in environmental control, advanced life support systems, and advanced space station crew health care systems. These investigations will reduce technical, schedule, and cost risks associated with the development and operation of the **ISS.**

The Microgravity NASA/Mir Research Program (NMRP) seeks to mitigate risk in scientific, technological, logistical, and operational planning for the use of the International Space Station. Additional goals of the NMRP are to characterize the microgravity environment on Mir and to conduct specific United States investigations in microgravity and application research disciplines. The NMRP has utilized modified Space Shuttle experiment apparatus, flight samples, science operations, and data analysis/procedures in order to allow United States investigators to fully maximize the capabilities of the Mir Space Station.

The Space Biomedical Center for Training and Research, a collaboration between NASA and several Russian organizations, including the Russian Space Agency, the Ministry of Science and Technology Policy in Moscow, and the Institute of Biomedical Problems, established at the Moscow State University in 1995, continues to operate. This Center focuses on several activities including aerospace medicine training, medical education, telemedicine, and terrestrial applications of space technology from the Russian Space Program. Medical education is being supported between select U S medical centers and MSU using emerging telecommunications and information technologies.

**Utilization support**

Utilization support provides the necessary capabilities to provide access to the International Space Station (ISS) for payloads by commercial, academic and government researchers. These capabilities provide the facilities and systems 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 expected to maintain the least cost and highest flexibility to both the user community and NASA. User/payload operations are integrated to ensure compatible use of **ISS**

resources and to resolve payload requirement conflicts. Payload operations integration is provided across all United States and International Partner user operations. Once developed, user support services and systems will be maintained and available throughout the life of **ISS.**

A variety of facilities, services, and systems are provided for user/payload support. Utilization support services provides pre-flight payload checkout support, payload operations integration, payload training, mission planning, and analytical integration. These services are consolidated to eliminate duplication of effort and increase over all efficiency while supporting distributed payload operations by the user community. 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, capability for quick access by the user community, training of ground and flight teams, 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 including activity scheduling during the mission.

For the redesigned **ISS,** the payload integration process has been streamlined and significantly shortened. Standardized payload accommodations are provided for modularity, flexibility and streamlined manifesting of user payloads. ***An*** express rack concept has been adopted to drastically shorten user pre-flight payload preparation activities.

On the ground, the Payload Operations Integration Center (POIC)/United States Operations Center (USOC),Payload Data Services System (PDSS)and the Payload Planning System (PSS)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 requiring payload facility services, the USOC provides accommodations for payload users to conduct ground based operations. Development cost of these systems has been reduced by utilizing generic architecture which supports multiple programs including Space Shuttle, Spacelab, and the Advanced X-Ray Astrophysics Facility (AXAF).

Supporting pre-flight payload activities, utilization support includes user assistance services, payload checkout systems, and necessary support to prepare experiments for launch and on-orbit operation. Among the systems provided are the Payload Rack Checkout Unit (PRCU),and the Suitcase Test Environment for Payloads (STEP). A Payload Data Library (PDL) is provided to integrate all payload flight data for quick and efficient configuration of flight and ground payload systems.

Integrated services are also provided at the integrated **ISS** level to ensure full, efficient, and compatible user utilization of **ISS** resources including the International Partners. This function includes payload integration, training, and payload operations integration services. These services are supported by the POIC systems, and provide the final integration making the **ISS** a truly international resource.

**Research facilities**

As one of the primary NASA users of the Space Station, the Life and Microgravity Sciences and Applications program sponsors a robust program to develop flight experiment apparatus, ground-based facilities and operations protocols needed to make the Space Station's unique capabilities available to the United States. The program includes seven facilities and four projects: Human

Research Facility (HRF); Gravitational Biology Facility (GBF); Centrifuge Facility (CF);Space Station Furnace Facility (SSFF);Fluids and Combustion Facility (FCF); Biotechnology Facility (BTF) (which includes Protein Crystal Growth activities); Low-Temperature Microgravity Physics Facility (LTMPF); the Risk Mitigation Project, the Expedite the Processing of Experiments to Space Station (EXPRESS)Rack Project, the EXPRESS Pallet Project, and the Laboratory Support Equipment (LSE) project.

The HRF will define and develop space flight research hardware to serve a number of closely related objectives. The HRF hardware suite will enable the standardized, systematic collection of data from the Space Station's crew members, 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 commitment aboard the **ISS** will include the suite of hardware necessary to protect crew health. The Crew Health Care Subsystem (CHeCS)being developed by JSC will support medical care requirements for the **ISS** crew following deployment of the **U.S.** Laboratory module in late 1998. 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 will be evaluated, with the synergy between the two programs resulting in efficiencies and cost savings.

The combination of the GBF and CF make up a complete on-orbit laboratory for NASA's Biology Research Program. The two facilities will be developed in an integrated manner. The GBF will design, develop, and conduct the on-orbit verification of Space Station 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's 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 CF includes two habitat holding systems, a two-and-a-half meter diameter centrifuge rotor, life sciences glovebox, and a service system rack. The project will also include a biotelemetry system to support ground-based data analysis of in-flight experiments. The Space Station Program Office is pursuing negotiations with the Japanese to provide the centrifuge rotor, life sciences glovebox and the Centrifuge Accommodation Module in exchange for NASA-provided launch services or other offsets.

The BTF supports protein crystal growth and 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 (>50) of academic, commercial and government scientists. JSC will develop this facility.

The 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 facility core will provide common support systems for both the combustion and the fluids modules. The Fluids Module Experiment Rack will be 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 will house a combustion chamber that is equipped with ports to allow an array of modular diagnostic systems to view the experiment. LeRC will develop this facility.

The SSFF is used to study underlying principles necessary to predict the relationships of synthesis and processing of materials to their resulting structures and properties. The facility core, which will provide the main interface to the Space Station services, will consist of furnace subsystems common to many types of investigations. The experiment modules will be composed of multi-user or investigator-unique modules that will be designed for high reliability and long life. NASA will be able to reconfigure the modules and will have the capability of on-orbit reconfiguration to support many different types of investigations. It is anticipated that cooperative efforts with the international science community 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. MSFC will develop this facility.

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. An EXPRESS Rack concept has been adopted to drastically shorten user pre-flight payload preparation activities. The EXPRESS projects will provide an efficient payload integration capability for smaller payloads with a limited amount of resources. The EXPRESS Rack project will develop the racks and pallets necessary to accommodate these smaller payloads, within the pressurized volume as well as external attachments to the Station . 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 includes a precursor flight of an EXPRESS rack in FY 1997 on the MSL-1 Spacelab mission. EXPRESS racks will be available to support initial payload operations in the U.S. Laboratory on the ISS. The EXPRESS Pallet project provides small attached payloads with a similar streamlined process and hardware and software interfaces. MSFC is responsible for developing the EXPRESS Racks and Pallets.

Currently planned attached payloads include SAGE III, which measures stratospheric properties for ozone depletion research, and the Low Temperature Microgravity Physics Facility which accommodates fundamental physics experiments at very low temperatures in a microgravity environment. Also planned is the Alpha Magnetic Spectrometer, a cooperative project with the Department of Energy, which measures cosmic rays in order to perform fundamental cosmological research.

Laboratory Support Equipment (LSE) is also under definition review for the Space Station in order to support Life and Microgravity Sciences and other experiments. Four pieces of equipment are currently being reviewed. LeRC is reviewing the Film Locker and the electro-magnetic shielded locker. MSFC is reviewing the Video Camera and the Digital Thermometer. Both Centers are currently reviewing requirements and cost estimates for LSE and plan to revise facility development based on more specific requirements definitions. Other LSE items currently under study or in development at ARC include the passive dosimeter, specimen labeling tools, microscopes, small mass measurement device, pH meter, incubator and refrigerated centrifuge.

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 the activities, the commercial research programs for the **ISS** will concentrate on Commercial Protein Crystal Growth, 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 Integrated Space Station Engineering Center (ISSEC) at JSC is planned to maximize the use of the ISS as a unique on-orbit laboratory and to foster partnerships with other US Government. industrial. and academic communities. The ISS will be used for long duration and reconfigurable development of technology products that validate new concepts for civilian space activities. The ISSEC intends to identify, and define innovative technology concepts beginning in FY **1997,** then 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 ISSEC program will promote the fast track implementation of these experiments. At the same time, the ISSEC program intends to obtain proposals for the facilities which can provide the necessary support for one or more experiments to operate without duplication of functions.

The HRF development effort will be managed primarily as an in-house effort at JSC, but it will draw contractor support primarily from Lockheed-Martin and Krug Life Sciences. Lockheed-Martin will provide project engineering and related services in support **of** HRF hardware development and modification. Krug Life Sciences will support science requirements development and definition at JSC. The GBF and the CF projects will rely upon the international participation described below, as well as selected support contractors. The Lockheed-Martin Corporation will support science definition and development for the GBF and CF. Boeing is developing the Habitat Holding Rack for ARC. This rack is a derivative of the EXPRESS rack and will provide programmatic synergy and cost savings to the program. The BTF project is led by JSC, with contractor support from Krug Life Sciences Corporation. The FCF is led by the LeRC, with contractor support from the NYMA and Analex Corporations. The SSFF effort is led by the MSFC as an in-house effort. Boeing and Lockheed's Palo Alto Research Center are developing cryogenic freezers as part of the LSE Project.

NASA is actively pursuing international participation the Space Station facility projects. For example, the GBF project has contacted the space agencies of Japan and Canada to solicit their participation in the development of an aquatic habitat and insect habitat. A multilateral users working group, consisting of representatives from all the major ISS participating countries, has agreed to principles for eliminating redundant flight hardware. NASA and the European Space Agency (ESA) have established a bilateral agreement to develop three flight copies of a -80$^{o}$ C freezer. NASA and ESA also have a bilateral agreement in principal to develop a Microgravity Sciences Glovebox whose capabilities are specified by NASA and will be available for use by all international Space Station microgravity researchers. The Centrifuge Accommodation Module (CAM),the Centrifuge Rotor, and the Life Sciences Glovebox are being negotiated with the National Space Development Agency of Japan (NASDA). The Biological Research Program (BRP) is participating with the Hungarian Space Agency to develop passive radiation monitors and an on-board badge reader as part of the LSE Project. NASA will pursue other agreements of this sort in order to increase the science returns and the economies of the **ISS** program.

**Science utilization**

Space Station Science Utilization will enable researchers to use the ISS as a unique laboratory for the United States research and technology community. The utilization program will support the development of experiment-unique flight hardware, engineering support to United States Principal Investigators, ground-based facilities, and science operations in the biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, materials science disciplines, biomedical research, gravitational biology, and commercial applications.

## MEASURES OF PERFORMANCE

**Mir research and support**

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|---|---|
| Achieved six months of American crew time on Mir<br>Plan: 3rd & 4th Qtrs FY 1996<br>Actual: March - Sept. 1996 | Conducted life sciences and microgravity research aboard Mir. Actually achieved seven months of American crew time on Mir. |
| Spacehab pressurized module to Mir<br>Plan: 2nd & 4th Qtrs FY 1996<br>Actual: March, Sept. 1996 | Shuttle rendezvoused with and docked to Mir. Spacehab modules were used to transport Russian logistic items, U.S. and Russian science and technology payloads, and ISS risk mitigation payloads. |
| EVA spacewalk on Mir<br>Plan: 4th Qtr FY 1996<br>Actual: March 1996 | U.S. performed a spacewalk while docked to Mir to validate and demonstrate assembly techniques for the ISS and installed external experiments on the docking module. |
| Long Duration Mission (LDM)-3<br>Plan: Sept. 1996-Jan. 1997<br>Actual: Sept. 1996-Jan. 1997 | U.S. astronaut stays aboard the Mir space Station conducting life sciences and microgravity research. |
| Shuttle missions 5, 6, 7 to Mir<br>Plan: Jan., May, Sept. 1997 | Rendezvous and dock the Shuttle to Mir and perform crew exchange, logistics, and life science research. During STS 86 (Shuttle Mir-7) perform an EVA to retrieve external experiments from the docking module. |
| LDM-4<br>Plan: January - May 1997 | U.S. astronaut stays aboard the Mir space Station conducting life sciences and microgravity research |
| LDM-5<br>Plan: May - Sept. 1997 | U.S. astronaut stays aboard the Mir space Station conducting life sciences and microgravity research. |

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| Shuttle missions 8, 9 to Mir<br>Plan: January, May 1998 | Rendezvous and dock the Shuttle to Mir and perform crew exchange, logistics, and life science research. |
| LDM-6<br>Plan: Sept. 1997 - Jan. 1998 | U.S. astronaut stays aboard the Mir space Station conducting life sciences and microgravity research. |
| LDM-7<br>Plan: January - May 1998 | U.S. astronaut stays aboard the Mir space Station conducting life sciences and microgravity research. |
| NASA/Mir 2 Launch<br>Plan: 1st Qtr FY 1996<br>Actual: 1st Qtr FY 1996 | A docking module extension was attached to the Mir and will be used by the Shuttle for the remaining NMRP missions. Logistics and resupply for the U.S. experiments was accomplished ahead of plan due to efficiencies ('Lessons Learned") implemented as a result of the prior Shuttle/Mir mission experience. A database is being developed to transition the Phase I "Lessons Learned" into the Phase II/III Space Station Program. This mission was launched on schedule and was highly successful in the achievement of its scientific goals. |
| NASA/Mir 3 Launch<br>Plan: 2nd Qtr FY 1996<br>Actual: 2nd Qtr FY 1996<br><br>NASA/Mir 4 Launch<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Spacehab mission management and integration functions for these two module flights was performed by Spacehab, Incorporated. Life sciences research on Biorack investigated cellular functions and developmental processes in plant and animal tissues. Microgravity objectives focused on reducing scientific risk and enhancing long duration experiment performance and science utilization in preparation for the International Space Station. A multi-disciplined joint U.S./RSA research program was conducted on a continuous basis on board Mir during this period and beginning on Flight 3 NASA will have a U.S. astronaut on board Mir. |
| NASA/Mir 5, 6, 7 Launches<br>Plan: 2nd Qtr FY 1997 (Mir-5)<br>Plan: 3rd Qtr FY 1997 (Mir-6)<br>Plan: 4th Qtr FY 1997 (Mir-7) | Spacehab mission management and integration functions for module Flights 5. 6, and 7 will be performed by Spacehab, Incorporated. Life sciences research on Biorack will investigate cellular functions and developmental processes in plant and animal tissues. Microgravity objectives will be focused on reducing scientific risk and enhancing long duration experiment performance and science utilization in preparation for ISS. A multi-disciplined joint U.S./RSA research program will be conducted on a continuous basis on board Mir during this period, and NASA will have a U.S. astronaut on board Mir throughout the period. |
| NASA/Mir-8 Launch<br>Plan: 2nd Qtr FY 1998<br><br>NASA/Mir-9 Launch<br>Plan: 3rd Qtr FY 1998 | Spacehab mission management and integration functions for module Flights 8 and 9 will be performed by Spacehab, Incorporated. Life sciences research on Biorack will investigate cellular functions and developmental processes in plant and animal tissues. Microgravity objectives will be focused on reducing scientific risk and enhancing long duration experiment performance and science utilization in preparation for ISS. A multi-disciplined joint U.S./RSA research program will be conducted on a continuous basis on board Mir during this period, and NASA will have a U.S. astronaut on board Mir throughout the period. |

**Utilization support**

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| Deliver and integrate final front end processors into PDSS<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | The payload data services system (PDSS) provides the data handling software and network needed to distribute data from the TDRSS users at the POIC/USOC and other remote facilities. The front end processor unit is a key element in the reception of data from TDRSS. |
| Deliver two STEP production units<br>Plan: 4th Qtr FY 1996<br>Revised: 4th Qtr FY 1997 | Suitcase test environment for payloads (STEP) enables the verification of the payload to rack interface at remote payload development sites. First production unit was delayed to July 1997 to reflect ISS command and data handling development cycle and payload need dates. |
| Merge POIC/USOC and PDSS development to single Utilization Mission Support contract<br>Plan: 3rd Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Payload operations and integration center (POIC) and U.S. operations center (USOC) and PDSS will gain efficiencies in development effort by a single contractor. |
| Complete front end processor build<br>Plan: 3rd Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | The front end processor unit is a key element in the reception of data from TDRSS. It converts the encoded serial steam from the ISS into the user data packets for subsequent distribution. |
| Complete UF-1 baseline IDRD<br>Plan: 2nd Qtr FY 1997<br>Revised: 1st Qtr FY 1998 | The interface definition and requirements document (IDRD) describes the on-orbit resources (volume, power, data, etc.) allocated to all payloads. |
| HOSC annex operational readiness date<br>Plan: 3rd Qtr FY 1997 | Huntsville operations support center (HOSC) annex supports communications services for the POIC/USOC and PDSS. The annex houses the equipment to provide connection to ISS users remote locations for telescience operations. |
| Complete all POIC/USOC and facilities outfitting<br>Plan: 4th Qtr FY 1997<br>Revised: 1st Qtr FY 1998 | Includes workstation upgrades in payload operations integration center (POIC) and U.S. operations center (USOC) at MSFC. |
| Complete initial ISS configuration of POIC/USOC systems<br>Plan: 4th Qtr FY 1998 | POIC/USOC capabilities to support initial ISS payload operations for Utilization Flights 1 and 2. Capabilities are phased commensurate with availability of ISS flight resources. |

| Research facilities | Due to the current restructuring activity, most facilities' schedules are under review |
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| HRF Interim Design Review, Rack 1<br>Plan: 2nd Qtr FY 1996<br>Actual: 2nd Qtr FY 1996 | This review establishes the project development plan and ensures that research/science objectives have been properly translated into statements of requirements. |
| HRF Preliminary Design Review, Rack 1<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage. |
| HRF System Flight Design Review, Rack 1<br>Plan: 1st Qtr FY 1997 | This review verifies the suitability of the design in meeting the specified requirements and establishes its 'build-to" project baseline. 90% of flight drawings should be complete at this stage. |
| GBF Preliminary Design Review, Rack 1<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage. |
| GBF Critical Design Review, Rack 1<br>Plan: 3rd Qtr FY 1997<br>Revised: FY 1998 | This review verifies the suitability of the design in meeting the specified requirements and establishes its "build-to" project baseline.<br>90% of flight drawings should be complete at this stage. |
| Centrifuge Rotor and Life Sciences Glovebox Development Contract<br>Plan: 3rd Qtr FY 1996<br>Revised: Under review | In negotiations with NASDA. |
| FCF Core System Requirements Definition Review<br>Plan: 2nd Qtr FY 1996<br>Actual: 1st Qtr FY 1997 | This review establishes full scale development plans required for go ahead for development. |
| SSFF Core System Critical Design Review<br>Plan: 2nd Qtr FY 1996<br>Revised: Under review | This review verifies the suitability of the design in meeting the specified requirements and establishes its "build-to" project baseline. 90% of flight drawings should be complete at this stage. |

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| EXPRESS Rack/MSL-1 Delivery to KSC<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | At KSC the initial EXPRESS Rack that will fly on MSL-1 integrated with the initial payload and processed in preparation for launch in FY 1997. |
| EXPRESS Rack Critical Design Review<br>Plan: 2nd Qtr FY 1997 | This review verifies the suitability of the design in meeting the specified requirements and establishes its "built-to" project baseline. 90% of flight drawings should be complete at this stage. |
| EXPRESS Pallet Project Requirements Review<br>Plan: 1st Qtr FY 1997 | Review establishes the project development plan and ensures that research/science objectives have been properly translated into statements of requirements. |
| EXPRESS Pallet System Requirements Review<br>Plan: 2nd Qtr FY 1997 | Review establishes full scale development plans required for go-ahead for development. |
| EXPRESS Pallet Preliminary Design Review<br>Plan: 2nd Qtr FY 1998 | This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage. |
| SSFF Critical Design Review<br>Plan: 4th Qtr FY 1997<br>Revised: Under review | This review verifies the suitability of the design in meeting the specified requirements and establishes its "built-to" project baseline. 90% of flight drawings should be complete at this stage. |
| FCF Core System Preliminary Design Review<br>Plan: 2nd Qtr FY 1997<br>Revised: Under Review | This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage. |
| FCF Fluids Module Preliminary Design Review<br>Plan: 4th Qtr FY 1997<br>Revised: Under review | This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage. |
| LSE Begin manufacturing of Cold Storage Units<br>Plan: 3rd & 4th Qtrs FY 1996<br>Revised: TBD | IPR and TIM's held in FY 1996 for Quick/Snap and Cryo Storage Freezers. R/FR rephased to Flight 19A (Hab Outfitting Flight) when on-board volume becomes available. |

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| LSE Complete General purpose glovebox manufacturing<br>Plan: 4th Qtr FY 1997<br>Actual: Canceled | General purpose glovebox workstation for non-biological experiments in U.S. Module. This project was canceled because only one user had been identified for what was originally planned to be multi-use equipment. |
| Crew Health Care System (CHeCS) Complete Critical Design Review<br>Plan: 3rd Qtr FY 1996<br>Revised: 2nd Qtr FY 1997 | Provides crew health care system hardware included in the health maintenance system, and the countermeasure system required to ensure crew health and safety.<br><br>This activity and measure of performance was transferred from Space Station Development |
| CHeCS Complete manufacture and assembly of qualification hardware<br>Plan: 4th Qtr FY 1996<br>Revised: 3rd Qtr FY 1997 | This activity and measure of performance was transferred from Space Station Development |

## ACCOMPLISHMENTS AND PLANS

### Mir research and support

In November 1995, the STS-74 mission delivered a new Russian-built docking module to Mir to allow the Space Shuttle to dock in a more favorable position with the Mir. Two more Space Shuttle missions using Spacehab modules were flown to Mir in FY 1996. During FY 1996, American astronauts spent 7 months aboard the Mir station conducting life sciences and microgravity research. On the STS-76 mission, U.S. astronauts performed an extra-vehicular activity (EVA) to install external experiments on the docking module. U.S. astronaut crew training continued for upcoming flights aboard Mir.

The remainder of the microgravity experiment apparatus planned for Mir was delivered to Russia for installation in the Priroda module (March 1996) and subsequent Shuttle flights. This microgravity hardware included the Glovebox, the Microgravity Isolation Mount (MIM) (in collaboration with Canada), and biotechnology hardware to support protein crystal growth and tissue culture growth. The Space Acceleration Measurement System has continued to collect and record data to characterize the Mir microgravity environment and support the Microgravity experiments manifested on Mir.

In support of the ISS program and to take maximum advantage of the NASA/Mir opportunity, the Life Sciences Space Station Utilization program will use Space Shuttle flights to Mir to develop new technologies for life support and enhance capabilities for on-orbit environmental monitoring. In the life support area, Life Sciences will adapt urine processing, water processing, and atmospheric revitalization hardware designs for use as flight experiments. Life Sciences expects to use in-house and off-the-shelf designs for water and air quality testing and for crew restraints during medical procedures. Four of these life support and environmental systems experiments were launched in FY 1996, with remaining experiments scheduled for launch in FY 1997.

As part of the NASA/Mir Research Program (NMRP) activities in FY 1996, the Life Sciences and Microgravity research programs continued to successfully conduct experiments to define the **ISS** environment. **As** part of the year's activities the longest spaceflight by a U.S. astronaut was achieved (143 days), aboard Mir by astronaut Shannon Lucid. The NMRP program thereby augmented previous studies on the challenges to human physiology and behavior during long-duration space flight. The program also continued with its Russian partners to standardize U.S. and Russian radiation detection data. In addition, SpaceHab, Inc.'s Commercial Middeck Augmentation Module (CMAM), outfitted with the ESA's Biorack and a suite of life sciences experiments, flew to Mir for the first time on STS-76 in FY 1996.

In FY 1997, three more Space Shuttle-Mir missions will be flown, which include three Spacehab double modules. American astronauts will spend 12 months aboard Mir conducting research and gaining more long-duration space flight experience. On the seventh Mir mission (STS-86), there will be an EVA to remove external experiments from the docking module. The program will use the NMRP to further study the physiological and behavioral changes that occur during long-duration space flight. The NMRP in FY 1997 will also provide U.S. extramural investigators with continuing opportunities to conduct plant and animal investigations, including the second and third Biorack flights.

Systems engineering efforts will continue to support methodologies for advocacy and coordination of U.S. research requirements and implementation of processes and tools for mission planning for US payloads on future space platforms, primarily the phase II and III of the **ISS.** Space Station planning and integration efforts will intensify as the First Element Launch date of the **ISS** approaches (December 1997).

During FY 1998, two Shuttle flights to Mir will be flown which will include a Spacehab double module and a single module. American astronauts will spend 8 months aboard Mir conducting research. It is anticipated that the Mir Phase 1 program will be completed with the ninth Shuttle flight to Mir in May 1998. The Life Sciences and Microgravity research programs will continue science investigations aboard Mir through FY 1998. Life Sciences expects to conclude its participation in the NMRP with a successful suite of research and development results in human physiology and behavior and in animal and plant biology.

**Utilization support**

During FY 1996, the design and development of the payload training capability at the Johnson Space Center (JSC) and the physical integration capability at the Kennedy Space Center (KSC) were completed. The initial delivery of the POIC/USOC at the Marshall Space Flight Center (MSFC) was completed, as was the design of the initial PDSS capabilities. A demonstration of the payload data library (PDL) concept occurred in early FY 1996 and was followed by the start of full-scale development. Development of the Payload Rack Checkout Unit (PRCU) also began.

In FY 1997, development of the POIC/USOC and PDSS capabilities for initial ISS support will begin based on the completed designs. The PDL and PRCU will both complete development in FY 1997. Payload engineering for early Utilization flights will begin, including establishment of a template for each of the six utilization flights, operating plans, and wiring diagrams. In mid-FY 1997 payload training plans will be issued. Two of ten suitcase test environment for payload (STEP) units will be complete and

available for shipment to users and payload development sites in support of the early ISS utilization flights. Payload integration agreements will be baselined for UF-1 payloads.

In FY 1998, the initial software capabilities for the POIC/USOC to support initial ISS Utilization Flights 1 and 2 will be delivered. Outfitting of the POIC/USOC with equipment to support ISS operations and training will also occur in FY 1998. Development of initial PDSS capabilities in support of ISS Utilization Flights 1 and 2 will be completed and the system will be completing final verification in support of a delivery in the 1st Qtr of FY 1999. In addition, design and development for final POIC/USOC and PDSS capabilities will be initiated at the end of FY 1998.

**Research facilities**

The HRF project considered various procurement and development strategies during FY 1995 and determined that existing flight hardware can support the project's early research requirements adequately. The HRF activities will include modifications to existing flight hardware during FY 1996 and FY 1997. New hardware will also be developed, but it has determined that no prime contracts for major hardware development will be necessary during the project's life. JSC plans to rely upon its in-house contractor, Lockheed-Martin, for hardware engineering and development support.

During FY 1995 and early FY 1996, the HRF project finalized its science requirements through the HRF's science working group. In FY 1996, the project began modifying and developing HRF precursor research equipment to fly on the last two NMRP missions. The project will develop procedures for conforming to Russian policies and procedures related to biomedical monitoring and countermeasures. The HRF project will also proceed with the development of hardware for the first rack to support an FY 1999 launch. Beginning in FY 1996, the HRF project held meetings with the international community to discuss sharing hardware development for the first two racks. NASA anticipates that sharing arrangements with the ISS international partners for HRF hardware development will yield efficiencies and minimize hardware redundancies. The HRF project completed an interim design review for the initial rack system for the second quarter of FY 1996. It conducted a preliminary design review for the first rack during the third quarter of FY 1996. During the first quarter of FY 1997, the HRF project expects to conduct a system level final design review.

The HRF project also has responsibility for provision of the Crew Health Care Subsystem (CHeCS). CHeCS will provide for medical care for the ISS crew following deployment of the U.S. Laboratory module in late 1998. and will provide medical care, operational exercise, countermeasures and environmental monitoring aboard the ISS. In assuming the CHeCS responsibility, hardware commonality between CHeCS and the HRF will be evaluated, with the synergy between the two programs resulting in efficiencies and cost savings.

During FY 1995, the GBF focused on developing detailed system specifications for equipment and system-level designs for the project's space and ground segments. A rack level preliminary design review was completed in the fourth quarter of FY 1996, to be followed by a rack level critical design review during the third quarter of FY 1997. During FY 1996, GBF project activities also focused on developing various habitats that will integrate into the initial rack, e.g., incubator and cell culture units. Other GBF activities will include the development of habitat science evaluation hardware for testing by the science community. These science

tests will evaluate science utility of the GBF habitat designs. The first complement of GBF hardware is scheduled for flight in FY 1999, with a second rack scheduled for FY 2002.

During FY 1996, the CF project supported negotiations with NASDA to build the CF rotor and the life sciences glovebox. The project will continue in-house hardware development and test bedding at ARC, and it will proceed with science requirements definition. A rodent metabolism study now being performed by the Bioenvironmental Research Laboratory at the University of Illinois at Urbana-Champaign will continue, as will the rodent acoustic tolerance testing being done at San Jose State University. Life sciences established a combined CF/GBF science working group during FY 1995 to conduct a variety of new studies in support of both the GBF and CF activities. The CF project will continue to support science studies to evaluate and improve upon hardware designs and configurations.

In FY 1996, the BTF experiment control computer flew on Mir to control cell and tissue culture experiments. The Mir precursor flights will reduce the risk in the design and development of full facility operations for Space Station. The BTF Requirements Definition Review scheduled for FY 1996 was delayed. The project schedule is currently being reevaluated.

The combustion and fluids modules for the FCF completed their Requirements Definition Review in October 1996. After successful completion of the review, the facility will proceed to the preliminary design and development phase. The preliminary design review, scheduled for FY 1997, is under review. The current launch readiness date for the FCF is the third quarter of 2001.

The SSFF core will be fabricated after the Critical Design Review. Originally scheduled for December 1996, the facility schedule is under review. The current launch readiness date for the Core facility and the first instrument rack is the second quarter of FY 2002.

The hardware that is being developed for risk mitigation includes a treadmill (with vibration isolation technology), a heart rate monitor, a blood pressure and ECG monitor, and a cycle ergometer. Some **of** this equipment will be located in the Russian modules in order to provide required capabilities to support permanent human presence prior to assembly of the U.S. laboratory module. The development of this equipment is planned for completion by the end of FY 1997, in time for early deployment during the ISS assembly phase.

During FY 1996, testing and integration of the MSL-1 EXPRESS rack was completed, and the rack was delivered to the KSC for payload integration and launch processing. Design was completed for the Space Station EXPRESS rack configurations and assembly of hardware was initiated for qualification and acceptance testing. In FY 1997, the MSL Spacelab mission will demonstrate operations of science payloads on orbit using an EXPRESS rack. Fabrication and testing of the first EXPRESS rack to fly on the ISS will begin in FY 1977 to support launch readiness for the first ISS utilization flight in FY 1999. EXPRESS rack interface simulators will be fabricated for use by EXPRESS payload developers.

During FY 1997, the design specifications for the EXPRESS pallet will be completed and approved at the Systems Requirement Review. Preliminary design will be completed and the PDR will occur in FY 1998. The first two EXPRESS pallets will be delivered to KSC in FY 2000 where integration with the six payloads will occur. The EXPRESS pallets flight readiness is scheduled in FY 2001.

The Stratospheric Gas and Aerosol Experiment (SAGE III) is scheduled for flight in 2001 and will take advantage of both solar and lunar occulations to measure aerosol and gaseous constituents of the atmosphere. Ball Aerospace is responsible for development, and the instrument began Phase C/D development in November of 1994. Activities have progressed on schedule with the CDR completed in August 1996.

During FY 1997 and FY 1998, NASA's commercial research programs for the ISS will concentrate on Commercial Protein Crystal Growth, where the intent will be to increase the number of samples that can be processed in a given volume, to monitor and control growth conditions, and to develop a new generation of thermal enclosures for crystal growth. NASA's commercial protein crystal growth activities for ISS are underway at the Center for Macromolecular Crystallography. NASA's FY 1997 and FY 1998 commercial research programs for ISS will also emphasize plant growth research, where the activities of the Wisconsin Center for Space Automation and Robotics, the Center for Bioserve Space Technologies, and their industrial affiliates will use ISS to develop heartier and more resistant plant products and to attain pharmaceutical advances using plants. The Integrated Space Station Engineering Center (ISSEC) will issue a cooperative agreement in the first quarter of FY 1997. Proposals for the ISSEC are planned for the second quarter of FY 1997, with evaluations to be completed in the third quarter of FY1997.

**Science utilization**

Life Sciences Space Station utilization activities will support the infrastructure development for Life Sciences Research facilities. Activities include developing initial training plans, preliminary definition of User Operation Facility requirements, experiment management approaches, initial crew procedures, baseline logistics, and the development of baseline data collection requirements for biomedical research. Life Sciences Space Station utilization also provides training for crew procedures and real-time operations, and supports the development of sustaining engineering and logistics systems and processes, experiment reviews, and the preparation of ground operations documentation.

The Microgravity Sciences program consists of planning and integration activities, developing operations support procedures, and developing experiment unique research hardware for the ISS. The microgravity program has continued the definition, design, and development of its Space Station facilities to meet its long-term program goal to deploy several multi-user facilities specifically designed for long-duration scientific research missions aboard the International Space Station. To prepare for microgravity operations on the ISS, work continues to define operational requirements and develop telescience techniques. Operational capability for microgravity research will be developed at MSFC, JSC, LeRC, and JPL.

Hardware design efforts will continue for the Physics of Colloids in Space (PCS) experiment. The science objectives are to create novel structures from colloidal particles and to study the dynamics of their formation and physical properties. The experiment will include studies of binary mixtures to form ordered and disordered structures in the formation of fractal colloidal aggregates. This is a follow-on to the PHaSE experiment scheduled to fly on the March 1997 MSL-1 mission that will take advantage of a significant design heritage. The PCS is planned to be the first Fluid Physics discipline experiment to be conducted on the ISS and launched on one of the early utilization flights.



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US/Russian
Cooperative
Program

HUMAN **SPACE FLIGHT**

**FISCAL** YEAR **1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF SPACE FLIGHT** **U.S./RUSSIAN COOPERATIVE PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Russian Space Agency contract support | 100,000 | 100,000 | -- | HSF2-1 |
| Total | 100,000 | 100,000 | -- | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | 99,200 | 100,000 | -- | |
| Kennedy Space Center | 800 | -- | -- | |
| Total | 100,000 | 100,000 | -- | |

**PROGRAM GOALS**

The United States and the Russian Federation have underway a joint cooperative space program to accomplish six major goals. First, the program permits us to develop, maintain, and enhance capabilities and operations to allow humans to live and work continuously in space. Second, by establishing a relationship with Russia as an international partner for the human exploration and exploitation of space, the United States can reduce the cost of future U.S. space initiatives by applying Russian-developed technology. Third, by flying Space Shuttle missions to the Russian Mir, the United States can enhance its understanding of long-duration operations, and gain life sciences and microgravity research benefits from long-duration experimentation. Fourth, early cooperation with the Russians permits us to develop common systems and operating procedures which will increase the probability of success and mitigate risks in the design, assembly, and operation of the International Space Station **(ISS)** in which they are a full partner. Fifth, by engaging Russia in constructive space work, the United States can advance its foreign policy initiatives. Finally, this relationship between the U.S. and Russian space agencies advances U.S. national space programs as well as U.S. aerospace industry.

## STRATEGY FOR ACHIEVING GOALS

The U.S./Russian cooperative program includes only the contract with the Russian Space Agency (RSA) which provides services and hardware for Phase I and selected Phase II activities related to the International Space Station (ISS) program. The budget for the ongoing Shuttle/Mir program has been transferred to the ISS program from the Science, Aeronautics and Technology account, and is discussed in that budget section.

Phase I of the program expands the joint participation by U.S. and Russian crews in Mir and Space Shuttle operations. This expanded program uses the unique capabilities of the Space Shuttle and the Russian Space Station Mir and provides support for nine flights to Mir. including seven long-duration stays of U.S. crew. Phase I provides valuable experience and test data which will greatly reduce technical risks associated with the construction and operation of the ISS and provides early opportunities for extended scientific and research activities. The Russian Space Station's capabilities have been enhanced by contributions from both countries. The Space Shuttle has delivered new Russian-built solar arrays to replace exisiting arrays on Mir, and one of these new arryas uses solar cells provided by the U.S.. Russia has launched the Spektr and Priroda modules to its station, equipped with U S., Russian, and other international scientific hardware to support science and research experiments. In **1996,** NASA added an eighth and ninth shuttle flight to Mir. The additional flights are consistent with the Gore-Chernomyrdin Commission protocol signed on January **30, 1996.** These additional flights will assist Russia in meeting its commitment to deliver key elements used in the early assembly of the ISS and will permit additional NASA astronauts to perform long-duration missions on Mir. The eighth and ninth Mir flights will use the Space Shuttle to reduce a significant logistics shortfall on Mir, conduct vital engineering research and expand our knowledge and experience of the effects of long-duration weightlessness. In addition, these extended Mir operations will assist Russia in its objective to extend the Mir on-orbit lifetime through FY **1999.** This approach takes into account the joint US/Russian interest in continuation of the Shuttle/Mir program, while minimizing changes to the ISS development plan.

Phase II combines U S. and Russian hardware to create an advanced orbital research facility with early human-tended capability. This facility will significantly expand the scientific and research activities initiated in Phase I, and will form the core of the ISS. Selected Phase II activities in the contract develop the systems capabilities, support, and other infrastructure to complete the ISS.

Under a bed-price contractual arrangement with NASA, the RSA will furnish supplies and/or services to enhance Mir operational capabilities, perform joint space flights, and conduct joint activities which will assist in the design, development, operations, and utilization of the ISS.

During Phase I, the RSA will provide management, Mir lifetime extension, Mir capabilities expansion, docking hardware and mission support for both long-duration and short-term, joint missions. Management activities include project documentation, and program and subcontract management. Mir lifetime extension includes system requirements planning, communication and control systems analyses and upgrades, thermal control documentation and requirements definition, environmentally-closed life support system (ECLSS) upgrades, power supply system upgrades, and propulsion systems documentation. To expand Mir capabilities, Spektr and Priroda modules were attached to the Mir for scientific use by Russia and the U.S.

Phase II combines U.S. and Russian hardware creating an advanced orbital research facility which enables early permanent human presence. This facility forms the core of the ISS. During this phase, the RSA will provide management, advanced technology. ISS elements, and associated analyses. ISS elements include: requirements definition of a joint airlock and delivery of androgynous peripheral docking system (APDS) hardware: service module modifications; FGB energy block modifications: delivery of repress/depress pumps for the airlock: and study and documentation related to a scientific power platform.

**MEASURES OF PERFORMANCE**

For this cooperative program, the level of performance will be measured by clearly defined, discrete results including successful docking and undocking of the Space Shuttle and Mir, successful joint operations between the Space Shuttle and Mir, exchange of crew, and delivery of both pressurized and unpressurized cargo. However, the most important and meaningful indicator of success will be completing the joint missions with our Russian partners, demonstrating our ability to work together in space safely and effectively, and laying the foundation for the unprecedented scope of our joint endeavor in building and operating the ISS.

The following events represent significant milestones in the successful completion of the U.S./Russian Cooperative program:

| | |
|---|---|
| Deliver hardware for U.S. Experiments on Priroda<br>Plan: 3rd Qtr FY 1996<br>Actual: 1st Qtr FY 1996 | Designed, fabricated, tested and installed hardware for U.S. experiments on Priroda. |
| Launch U.S. experiments on Priroda<br>Plan: 2nd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Priroda launch carried additional U.S. science experiments and equipment. |
| Deliver airlock depress/ repress pump assembly<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Delivered airlock depressurization qualification unit. |
| Delivery of passive docking mechanisms<br>Plan: 3rd & 4th Qtrs FY 1996<br>Revised: 1st Qtr FY 1996, 3rd Qtr FY 1997 | Delivery of two passive docking mechanisms (Passive 1 and 2), associated avionics, control panels, and documentation to support Phase II Space Shuttle flights to the ISS. |

| | |
|---|---|
| Delivery of docking mechanisms<br>Plan: 2nd, 3rd, & 4th Qtrs FY 1997 and 1st Qtr FY 1998<br>Revised: 2nd & 3rd Qtrs FY 1997: 1st, 2nd & 3rd Qtrs FY 1998 | Delivery of five docking mechanisms, associated avionics and control panels for ISS/Shuttle. |

**ACCOMPLISHMENTS AND PLANS**

Deliverables paid in FY 1996 were based on a total of 164 achieved milestones. Major work undertaken includes modifications to an active docking mechanism, continued implementation of the integrated science research plan, delivery of qualification and flight hardware for the depress/repress pump assembly, delivery of two passive docking mechanisms, and production of consumable supplies for astronauts. In addition, NASA expects RSA to conduct crew training and crew medical support, and to provide appropriate support for long-duration missions. In FY 1996, American astronaut Shannon Lucid spent 7 months aboard Mir conducting life sciences and microgravity research.

For FY 1997, deliverables to be achieved number 196. Major activities to be conducted include Stage 2 crew training and crew medical support, delivery of ground support equipment, continued implementation of the integrated science plan, delivery of three docking mechanisms, delivery of astronaut consumable supplies, and modifications to the service module. During FY 1997, American astronauts will be continuously aboard Mir conducting scientific research. Funding for the original $400M RSA contract under the U.S./Russian cooperative program concludes in FY 1997. However, some milestones, such as delivery of two docking mechanisms and two Shuttle docking missions to the Mir, will occur in FY 1998.

## HUMAN SPACE FLIGHT

## FISCAL YEAR 1998 ESTIMATES

## BUDGET SUMMARY

**OFFICE OF SPACE FLIGHT** **SPACE SHUTTLE**

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | (Thousands of Dollars) | | | |
| Safety and performance upgrades.. | 658,400 | 636,000 | 483.400 | HSF 3-4 |
| Shuttle operations | 2.485.400 | 2.514.900 | 2.494.400 | HSF 3-20 |
| Total | 3.143.800 | 3.150.900 | 2.977.800 | |
| D' 'bution of Program Amount by Installation | | | | |
| Johnson Space Center | 1,006,300 | 976,300 | 1,061,100 | |
| Kennedy Space Center | 795,800 | 777,600 | 753,800 | |
| Marshall Space Flight Center | 1,265,900 | 1,330,100 | 1,101,900 | |
| Stennis Space Center | 51,700 | 40,500 | 33,900 | |
| Dryden Flight Research Center.. | 5,600 | 5,400 | 5,900 | |
| Goddard Space Flight Center | 100 | -- | -- | |
| Jet Propulsion Laboratory | 200 | -- | -- | |
| Headquarters | 18200 | 21,000 | 21,200 | |
| Total | 3.143.800 | 3.150.900 | 2.977.800 | |

### *GENERAL*

The Space Shuttle budget is divided into two categories: Safety and Performance Upgrades (S&PU) and Shuttle Operations. It is distributed to the various program elements through the four Office of Space Flight Centers and the Dryden Flight Research Center.

The Space Shuttle program provides launch services to a diversity of customers, supporting payloads that range from small hand-held experiments to large laboratories. While many missions are devoted to NASA-sponsored payloads, wide participation is exercised by industry, partnerships and corporations, academia and other national and international agencies. Both NASA and

the U.S. scientific community are beneficiaries of this approach. The Space Shuttle is a domestically and internationally desired research facility because of its unique ability to provide on-orbit crew operations, rendezvous/retrieval, and payload provisions, such as power, telemetry, pointing and active cooling to payloads.

The Space Shuttle has numerous cooperative and reimbursable payloads involving countries and international agencies. Examples of international participation which the Space Shuttle is uniquely suited to support include:

- the retrieval of the Japanese space flyer unit in early 1996
- the reflight of the Italian tethered satellite system in early 1996
- the flight of the CRISTA-SPAS free-flying payload, equipped with an international cargo of science instruments in mid-1997.

The Space Shuttle program is also integral to the domestic commercial development of space, providing 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. Over 50 payloads with numerous experiments have been developed through these consortia were flown in FY 1996. Cooperative activities with the National Institute of Health (NIH), the National Science Foundation (NSF), the Department of Defense and other U.S. agencies are advancing knowledge on human health, medicine, science, and technology. Space Shuttle support for the flight of Neurolab in FY 1998, a major cooperative NASA-NIH program, is a prime example.

The Space Shuttle Program, on average, is safely flying more flights at less cost than ever before in the history of the program. The restructuring activities of the past five years have resulted in net dollar savings of 27% by FY 1997, equating to 25% less workforce, Reliability has improved by decreasing probability of catastrophic loss of the vehicle on ascent from 1 in 78 launches to 1 in 248, as estimated in the Probabilistic Risk Assessment report (SAIC Corporation, 1995). In addition, after 80 successful missions, a significant reduction in operational requirements is continuing. For example, in 1989, 1.6 million hours were required to process a Space Shuttle mission; today it is one-third of that number. Consolidation of contracts into a single prime contract was accomplished with the award of the Space Flight Operations Contract on October 1, 1996. This transition is scheduled to be completed in the next two years. The Space Shuttle continues to prove itself as the most versatile vehicle ever built, as demonstrated by performing rendezvous missions with the Russian Space Station Mir; advancing life sciences and technology through long-duration Spacelab and Spacehab missions; repairing and servicing the Hubble Space Telescope; enabling discovery of new astronomical events; rescuing and retrieving spacecraft: and preparing for the historic assembly of the International Space Station. This budget request further positions the Space Shuttle program to meet the challenges of space travel in the next century with an increased degree of safety and a decreased need for public funding.

## PROGRAM GOALS

The program goals of the Space Shuttle program are in priority order: 1) fly safely; 2) meet the flight manifest: 3) improve supportability: and, 4) reduce costs. These goals are reflected in our decisions regarding flight requirements, budget reductions

and programmatic changes. The flight rate for FY 1996 was eight successful flights. The FY 1997 and FY 1998 flight rate is seven flights per year. For FY 1999 and FY 2000, the flight rate is eight per year due to the addition of another Mir mission to the manifest and the new Shuttle Radar Topography Mission (SRTM), a joint DOD/NASA mission. This manifest supports the nation's science and technology objectives through scheduled Spacelab, Spacehab and other science missions, cooperative missions to the Russian space station Mir, and assembly of the International Space Station.

In addition to flying safely, restructuring the program, and conducting the single prime contract consolidation, we are continuing our emphasis on the Safety and Performance Upgrades program. This program includes a selected set of projects designed to improve the Space Shuttle safety and to improve performance by 13,000 pounds, allowing the Orbiter to achieve the orbital inclination and altitude of the International Space Station and support its assembly beginning in FY 1998. This budget also includes additional upgrades to allow the program to continue to fly safely and meet customer requirements in the most efficient manner practicable well into the next century. The program has initiated a supportability upgrade program should the Shuttle be required to operate past 2012. These upgrades address all elements of the Space Shuttle program and are managed through an approval process ensuring that new projects are evaluated, approved and initiated on a priority basis. The process also ensures that existing projects are meeting established cost and schedule goals.

## STRATEGY FOR ACHIEVING GOALS

The budget structure of the Space Shuttle program consists of two major components: Safety and Performance Upgrades and Space Shuttle Operations. Safety and Performance Upgrades provides for modifications and improvements to the flight elements and ground facilities, including expansion of safety and operating margins and enhancement of Space Shuttle capabilities as well as the replacement of obsolete systems. Shuttle Operations including hardware production, ground processing, launch and landing, mission operations, flight crew operations, training, logistics, and sustaining engineering. In addition, this budget includes funding for facilities related to the Space Shuttle.

The Space Shuttle program's strategy for the Safety and Performance Upgrades budget is to provide for the safe. continuous, and affordable operations of the Space Shuttle system, at a minimum, throughout the Space Station era (2012).

The overall strategy for the Shuttle Operations budget is to request funding levels sufficient to meet the intended flight rates, including appropriate contingency planning in both budget and scheduled allowances to assure transportation and assembly support to the Space Station program, while at the same time seeking opportunities to eliminate marginal value-added activities which enables reductions in operations costs. The Space Flight Operations Contract (SFOC) represents a key element of this strategy.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SAFETY AND PERFORMANCE UPGRADES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Orbiter improvements | 271,400 | 169,900 | 137,300 |
| Multifunction electronic display system | 40,600 | 32,400 | 15,300 |
| Simplified aid for EVA rescue | 7,100 | 7,800 | -- |
| Global positioning system | 9,200 | 9,600 | 1,300 |
| Other orbiter improvements | 214,500 | 120,100 | 120,700 |
| [Supportability Upgrades] [included above] | | [50,000] | [50,000] |
| Propulsion upgrades | 272,000 | 342,800 | 247,000 |
| Space shuttle main engine upgrades | 234,100 | 324,500 | 231,200 |
| (Alternate Turbopump program) | (97,000) | (95,400) | (96,200) |
| (Other main engine upgrades) | (137,100) | (229,100) | (135,000) |
| Solid rocket booster improvements | 7,200 | 800 | 6,600 |
| Super lightweight tank | 30,700 | 17,500 | 9,200 |
| Flight operations & launch site equipment upgrades | 97,600 | 115,000 | 92,300 |
| Flight operations upgrades | 73,400 | 89,000 | 51,500 |
| Launch site equipment upgrades | 24,200 | 26,000 | 40,800 |
| [Supportability Upgrades] | | [20,000] | [45,000] |
| Construction of facilities | 17,400 | 8,300 | 6,800 |
| Modernize fire system. pads A and B | (5,000) | | |
| Replace space shuttle main engine processing facility | (4,900) | | |
| Replace chemical analysis facility | (7,500) | | |
| KSC pad B fixed service structure/elevator | | (1,500) | |
| KSC pad B chiller | | (1,800) | |
| SSC high pressure water system refurbishment | | (2,500) | |
| MSFC Michoud assembly facility electric distribution | | (2,500) | |
| MSFC/MAF 480V Electrical Distribution System Phase II | | | (2,800) |
| KSC Pad A PRC Wall and Ceiling Integrity/Safety | | | (2,200) |
| KSC Pad A Surface and Slope Restoration | | | (1,800) |
| Total | 658,400 | 636,000 | 483,400 |

*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 operation of the Space Shuttle Orbiter. Success depends on developing these projects and getting them implemented to help insure the Space Shuttle's safe operation, and improve the reliability of the supporting elements.

The FY 1998 budget includes activities in the following categories: Orbiter Improvements, Space Shuttle Main Engine (SSME) Upgrades, Super Lightweight Tank (SLWT) development, Launch Site Equipment (LSE) Upgrades and Flight Operations Upgrades, as well as specific, Space Shuttle-related Construction of Facilities. This budget also includes Supportability upgrades to develop more advanced systems which will combat obsolescence of vehicle and ground systems in order to maintain the program's viability into the next century. Vendor loss of aging components, high failure rates of older components, high repair costs of Shuttle-specific devices, and negative environmental impacts of some out-dated technology are areas to be addressed. The Supportability Upgrades will be studied and initiated in FY 1997. As stated in the FY 1997 Initial Operating Plan letter, dated December 20, 1996; $70 million will be applied to these upgrades from available reserves and uncosted obligations. In FY 1998, our request includes $95M to continue those upgrades increasing reliability and maintainability of the Shuttle systems and also to continue studies to assess feasibility of implementing more state-of-the-art technologies into the system. This did not increase the previously planned FY 1998 funding level for the Space Shuttle program, The program has identified internal offsets, largely in the form of program reserves and improved management of uncosted carryover balances.

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 not 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 contract arrangements with Boeing North American (formerly, the Rockwell International Space Division) in two major locations in FY 1998: the Downey, California facility provides engineering, manufacturing and testing; and the Palmdale, California operation provides Orbiter Maintenance Down Period (OMDP) support discussed below. 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 Standard.

Orbiter Maintenance Down Period (OMDP) occurs when each 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 the Boeing North American Corporation is responsible for operating three locations that provide engine manufacturing, major overhaul, component 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. Development of the Super Lightweight Tank is managed by the MSFC and is being accomplished by the Lockheed Martin Corporation at the government-owned Michoud Assembly Facility (MAF) near New Orleans, LA.

### 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, the **T-38** aircraft and the Space Shuttle Carrier Aircraft (SCA). 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).

### Construction of Facilities

Construction of Facilities (CofF) funding for Space Shuttle projects is provided in this budget to refurbish, modify, 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 planning assumes continued utilization of the Space Shuttle through the year 2012, which is the planned life span of the International Space Station. In order to maintain a viable, human transportation capability that will operate into the next century and support NASA's launch requirements, specific program investments are required. These investments will be consistent with NASA's strategy of funding a series of safety, performance, and supportability Shuttle upgrades while we await a decision in the year 2000 concerning the future space transportation capability beyond 2012.

## 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 reduction in operational costs. Work continues on the Alternate Fuel Turbopump and new Large Throat Main Combustion Chamber (LTMCC) for the planned introduction of the block II Space Shuttle Main Engine (SSME) in late CY 1997.

The major safety and performance upgrades and their initial flight dates are listed on the following chart on the next page.

## MEASURES OF PERFORMANCE

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 and to help ensure the Space Shuttle's safe operation, improve the 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

Simplified Aid for EVA Rescue (SAFER) - SAFER is a small self-contained, one person free-flyer unit which provides an EVA self-rescue capability for the astronauts should they become inadvertently untethered from the Space Shuttle or International Space Station.

| | |
|---|---|
| Initial SAFER Flight Demonstration<br>Plan: 4th Qtr FY 1996<br>Actual: 2nd Qtr FY 1996 | Demonstrate on STS-64 flight.<br><br>The unit was utilized for the first time on the STS-76/Mir-03 flight. |
| Conduct Preliminary Design Review (PDR) for SAFER<br>Plan: 2nd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Completion of PDR will allow design of the production units to proceed toward CDR. |

# SPACE SHUTTLE PROGRAM SAFETY AND PERFORMANCE ENHANCEMENTS

## HEDS STRATEGIC PLAN

| Fiscal Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Alternate Turbopump Development | | | | | | | | |
| -- Oxidizer Turbopump - First Flight | ▲ 7/95 | | | | | | | |
| -- Fuel Turbopump - First Flight | | | | △ 12/97 | | | | |
| Large Throat Main Combustion Chamber - First Flight | | | | △ 12/97 | | | | |
| Super Lightweight Tank - First Flight | | | | △ 12/97 | | | | |
| Main Engine Phase II + Powerhead - First Flight | ▲ 7/95 | | | | | | | |
| Auxilary Power Unit - New Gas Generator Valve - Ready for Flight | | | △ 5197 | | | | | |
| Multifunction Electronic Display System - First Flight | | | | | △ 1199 | | | |

**OPR:** Bill **Bihner NASNME;8/12/96**

| | |
|---|---|
| Conduct Critical Design Review (CDR) for SAFER<br>Plan: 4th Qtr FY 1996<br>Revised: 1st Qtr FY 1997 | Completion of CDR will allow production to proceed so that SAFER will be available for joint Space Shuttle-Mir Joint spacewalk on STS-86/Mir-07 Flight in FY 1997. |

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.

| | |
|---|---|
| Complete MEDS Qualification Testing<br>Plan: 1st Qtr FY 1996<br>Revised: 2nd Qtr FY 1997 | Complete hardware qualification testing and start hardware integration and verification testing.<br>The qualification program was extended through this date. No significant impact to initial operating capability is expected. Delay was due to change in glass supplier. |
| MEDS Initial Operational Capability (IOC)<br>Plan: 4th Qtr FY 1998<br>Revised: 2nd Qtr FY 1999 | First flight of a MEDS equipped Orbiter.<br>Revised due to glass supplier change. |

Global Positioning System (GPS) - GPS will replace TACAN in the Orbiter navigation system when the military TACAN ground stations will be phased out in the year 2000. The planned readiness date for the Space Shuttle's system is FY 1999.

| | |
|---|---|
| Complete GPS Preliminary Design Review (PDR)<br>Plan: 4th Qtr FY 1996<br>Revised: 2nd Qtr FY 1997 | Completion of System Requirements Review will allow design drawings to proceed toward CDR.<br>Delay is due to a change in the procurement from the originally-planned, single-string GPS, to the GPS Inertial Navigation System (INS), which will have broader applications (e.g., RLV, ISS) than the previous version. |
| Complete GPS System Requirements Review<br>Plan: 4th Qtr FY 1996<br>Revised: 2nd Qtr FY 1997 | Completion of CDR will allow drawings to be released for production to proceed.<br>Delay is due to the change from the original, single-string GPS, to the GPS Inertial Navigation System. |
| Complete GPS operational capability<br>Plan: 2nd Qtr FY 1999 | Initial operation of GPS without TACAN system. |

Orbital Maintenance Down Periods

| | |
|---|---|
| Complete Discovery (OV-103) OMDP<br>Plan: 1st Qtr FY 1997<br>Actual: 3rd Qtr FY 1996 | Conduct routine maintenance; outfit Discovery with external airlock; fifth cryogenic tank; preparations for Shuttle rendezvous with Mir and the International Space Station.<br><br>Rephased/advanced schedule to meet manifest requirements. |
| Initiate Endeavour (OV-105) OMDP<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Conduct routine maintenance; prepare Endeavour for the International Space Station operations; outfit with external airlock.<br><br>Endeavour is presently at Palmdale. |

**Propulsion Upgrades**

Super Lightweight Tank - This performance enhancement is designed to provide 7,500 pounds of additional performance for the Space Shuttle to allow rendezvous and operations with the International Space Station.

| | |
|---|---|
| Aluminum-Lithium Test Article (ALTA) testing complete<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Completion of testing will certify the structural integrity of the external tank design and fabrication process. |
| Design Certification Review<br>Plan: 2nd Qtr FY 1997<br>Revised: 3rd Qtr FY 1997 | The Super Lightweight Tank will provide 7,500 pounds of performance through incorporation of an aluminum-lithium alloy in the external tank structure.<br>Revised due to welding proof tests. |
| Deliver first SLWT to KSC for flight<br>Plan: 4th Qtr FY 1997 | Final assembly and checkout will be conducted at the Michoud Assembly Facility (MAF) in New Orleans, Louisiana. |

Space Shuttle Main Engine Safety Improvements - Introduction of Block I and Block II changes into the Space Shuttle's Main Engine program will improve the margin of safety by a factor of two (2).

| | |
|---|---|
| High Pressure Fuel Pump Critical Design Review (CDR)<br>Plan: 3rd Qtr FY 1996<br>Revised: 2nd Qtr FY 1997 | Completion of CDR will allow production to proceed for implementation of the ATP high pressure fuel pump into the Block II Engine upgrade.<br>The delay is the result of several technical problems experienced in the fuel pump design, discovered during testing, which are being modified and retested. |

| | |
|---|---|
| First flight of the Block II engine<br>Plan: 4th Qtr FY 1997<br>Revised: 1st Qtr FY 1998 | The high pressure fuel turbopump will be combined with the large throat main combustion chamber (LTMCC].<br><br>Revised due to testing delays resulting from technical design difficulties. |

**Flight Operations and Launch Site Equipment Upgrades** - Upgrades to the Mission Control Center will occur during FY 1996-98 period improving operations reliability and maintainability and also taking advantage of the state-of-the-art technology in displays and controls. In addition, upgrades to the Launch Processing System in the Launch Site Equipment budget at KSC will increase reliability and reduce obsolescence.

| | |
|---|---|
| Begin ascent/entry mission support from new MCC<br>Plan: 1st Qtr FY 1996<br>Actual: 2nd Qtr FY 1996 | Complete entire mission profile with the new MCC during STS-73 mission. |
| Replacement of displays and controls<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Installation of new state-of-the-art system will allow more efficient operations. |
| New MCC front end implementation and equipment replacement<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Implementation of new commercial off-the-shelf (COTS) system will allow removal of obsolete custom built equipment and consoles with significant reduction in life cycle costs. |
| Implementation of new MCC command server system<br>Plan: 4th Qtr FY 1997 | Removal of command functions from the mainframe Mission Operations Computer (MOC) is a major step which will significantly reduce command and control life cycle costs. |
| Complete development of the new Consolidated Planning System (CPS) and phase-out of Flight Planning System<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Implementation of the new commercial off-the-shelf (COTS) hardware/software based planning system will enable phase-out of existing higher life cycle cost FPS and enable common planning tool for Space Shuttle and Station operations. |

**Launch Site Equipment Upgrades**

| | |
|---|---|
| Deliver first two Portable Purge Units | First units delivered and tested by user. |
| Plan: 4th Qtr FY 1996<br>Revised: 3rd Qtr FY 1997 | Revised due to delay in award of contract. |

**Construction of Facilities**

| | |
|---|---|
| Replace Fire Protection Pumps and Piping at LC-39/A&B | Pumps are currently inadequate to provide spray coverage during an emergency. |
| Phase I<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Pad A Complete. |
| Phase II<br>Plan: 3rd Qtr FY 1997<br>Revised: 4th Qtr FY 1997 | Pad B work to be accomplished during down time of launch pad - January 97 to August 97. |
| Replace Component Refurbishment and Chemical Analysis Facility at KSC | Facility is 25 years old, in non-compliance with OSHA standards, overcrowded and insulated with asbestos. Completing this effort in FY 1997 is earliest opportunity to comply with CFC requirements during cleaning and degreasing operations. |
| Phase I<br>Plan: 2nd Qtr FY 1996 | Complete activation of component refurbishment building. |
| Revised: 1st Qtr FY 1997 | Delay due to extended negotiation with the activation contractor. |
| Phase II<br>Plan: 2nd Qtr FY 1996 | Begin construction of chemical analysis facility. |
| Revised: 4th Qtr FY 1996 | Revised plan due to delay in FY 1996 appropriation bill. |
| Phase II<br>Plan: 2nd Qtr FY 1997<br>Revised: 4th Qtr FY 1997 | Completion of construction. |

| | |
|---|---|
| SSME Processing Facility | Project provides for construction of an addition to the east end of the lower level of OPF-3 Annex. |
| Plan: 4th Qtr FY 1996<br>Revised: 1st Qtr FY 1997 | Begin construction of SSME Processing Facility. |
| Complete Construction<br>Plan: 2nd Qtr FY 1998 | |
| Rehabilitation of 480V Electrical Distribution System | The 480-volt electrical distribution system in building 103 was originally installed in the 1940s. This project will replace feeder cables and distribution panels and it contains the systematic rehabilitation of the older high voltage system in critical ET production areas. |
| Phase I<br>plan: 4th Qtr FY 1996<br>Revised: 1st Qtr FY 1997 | Design Complete. Begin Construction. |
| Phase II<br>Plan: 3rd Qtr FY 1996<br>Revised: TBD | Begin Design. Estimated time for design - 12 months. |
| Restore Pad B Fixed Service Structure<br>Plan: 1st Qtr FY 1997<br>Revised: 2nd Qtr FY 1997 | This project replaces the elevator cabs, cables, and controls to eleminate severly deteriorated and archaic equipment.<br>Design Complete. Begin Construction when Pad B mod window begins. |
| Replace LC-39 , Pad B Chiller<br>Plan: 1st Qtr FY 1997<br>Revised: 2nd Qtr FY 1997 | This project replaces three existing facilitiicy chillers and air handling units.<br>Design Complete. Begin construction when Pad mod window begins. |
| Refurbishment of High Pressure Water System<br>Plan: 1st Qtr FY 1997<br>Actual: 4th Qtr FY 1996 | Overhaul diesel engine for the water pumps and backup electrical power need to ensure system reliabillity and maintainability in support of the SSME test program as well as future testing.<br>Design Complete. Begin construction. |
| Restore PCR Wall and Ceiling Integrity at LC-39A<br>Plan: 2nd Qtr FY 1997 | This project provides for replacement of damaged walls, leaking access door, ceiling/lighting improvements for safer accessibility and better environmental control of Payload Changeout Room<br>Begin design. |

| | |
|---|---|
| Restore Launch Pad A Surface and Slopes at LC-39A<br>Plan: 4th Qtr of FY 1996<br>Revised: 1st Qtr of FY 1997 | This project includes repair of cracks, repair/replacement of fractured and broken section of concrete.<br><br>Begin Design. |

## ACCOMPLISHMENTS AND PLANS

Budgetary pressures demand that proper investments are made to promote efficiency of operations while insuring that the critical element of safety is maintained as a primary goal. The FY 1998 budget request for Safety and Performance Upgrades is the result of a project prioritization process that addresses safety first, second it provides for performance enhancements, upgrades to prevent obsolescence and promote efficiency, and third. it addresses maintenance and logistics enhancements to improve reliability and operating efficiency in order to meet our manifest requirements.

A significant portion of the Safety and Performance Upgrades (S&PU) budget is dedicated to avoiding and preventing 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 will continue to support the replacement of the Orbiters' cockpit displays with Multifunction Electronic Display System [MEDS), replacing Tactical Air Command and 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 SSC, testing of Orbiter reaction control systems at the White Sands Test Facility, and replacing critical subsystems in the Kennedy Space Center facility complex. At the Kennedy Space Center, phase two of the fire protection upgrade will be conducted as will replacement of the chemical analysis lab and improvement of the main engine processing facility.

In addition, this request includes funds for Shuttle Supportability Upgrades which will maintain availability of the Space Shuttle fleet into the next century and, at a minimum, through the planned life of the International Space Station (2012).

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 will be planned and implemented from a system-wide perspective. Individual upgrades will be integrated and prioritized across all flight and ground systems, insuring 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 will be utilized. Implementation authority and

responsibility will be delegated to the Lead Center Director for the Shuttle Program with the Shuttle Program Manager and the projects. Space Shuttle upgrades will be 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
- Reduce Space Shuttle system operations cost

The phasing strategy will be coordinated with the Reusable Launch Vehicle (RLV) project management, and other development projects, to capture common technology developments, while meeting the Shuttle manifest. This phasing strategy should allow the incorporation of additional, more comprehensive upgrades to the Space Shuttle system while benefiting other programs and technologies. Definition activity leading to the selection of upgrade candidates will continue in FY 1997. Candidate upgrades in the initial phases will utilize state-of-the-art technology and provide safety/reliability, supportability, and/or cost (improvement) advantages. Candidate designs in the initial phases would maintain the current Shuttle mold lines and system/subsystem interfaces. Major system changes will likely require a definition period with the potential for the development of prototype systems.

**Orbiter Improvements**

Orbiter improvements provide for modifications and upgrades to ensure compatibility of the Space Shuttle vehicles with the new Space Station operational environment. Orbiter weight reductions have been identified where operating experience or updated requirements allow selected items to be changed without impact to crew safety or mission success. The Orbiter weight will be reduced by changing the exterior thermal protection materials on certain portions of the Orbiter, deleting portions of the Orbital Maneuvering and Reaction Control Systems (OMS/RCS) that are no longer required, changing the material on the "flipper doors" that provide a seal between the Orbiter wing and its control surfaces, and development of lighter weight crew seats for the cockpit.

Other improvements continue on the Orbiter internal systems. For example, the Auxiliary Power Unit gas generator valve module is undergoing redesign to improve its reliability; the thermal protection system certification will allow the leading edge of the wing to experience higher temperatures during reentry, a new vendor was qualified to provide remote power controllers, and enhancements for improving the Space Shuttle performance were initiated. The new Auxiliary Power Unit gas generator valve module will be ready for its first flight during the second quarter of FY 1997.

During FY 1996, Discovery (OV-103) completed its OMDP and will re-enter the fleet in time to fly STS-82 in February 1997. Endeavour (OV-105) followed Discovery and will complete the OMDP at the Palmdale, California facility for normal maintenance, structural inspections, and modifications for docking with the International Space Station, and is expected to be completed in April 1997. In FY 1998, Atlantis (OV-104) will enter OMDP for normal maintenance, structural inspections, and will also be modified for docking with the International Space Station.

The Multifunction Electronic Display System (MEDS) upgrade will replace the current Orbiter cockpit displays which are early 1970's technology. The current displays which provide command and control of the Space Shuttle are "single string" electro-mechanical devices that are experiencing life related failures and are maintenance intensive. Difficulty in obtaining parts, some of which are no longer manufactured. is becoming more prevalent. The MEDS upgrade is a state-of-the-art, multiple redundant liquid crystal display (LCD) system. MEDS will enhance the reliability of the cockpit display system, resolve the parts availability problem, and provide a much more flexible and capable display system for the crew. This upgrade will bring the Orbiter up to current aircraft standards, benefiting the training of new astronauts directly. Secondary benefits of MEDS are reductions in the Orbiter's weight and power consumption. The MEDS upgrade includes the design effort and production of modification kits for the four Orbiter vehicles. New MEDS ground support hardware is also being designed. When procured and installed it will upgrade the appropriate simulators, test equipment, and laboratories. MEDS will be installed in the Orbiters and tested during the planned OMDPs. The decision to make a switch to an alternate and more viable source for the Active Matrix Liquid Crystal Display Assemblies caused a six month delay in the first flight of a MEDS equipped Orbiter from July 1998 to January 1999.

Expansion of the effort to replace the Orbiter's TACAN landing navigation system with the Global Positioning System (GPS) began in FY 1995. This expansion will include an increased interaction of the GPS receiver with the Orbiter backup flight software, and outfitting two more Orbiters with a GPS test receiver. A number of development flights will take place with increasing GPS capability while still utilizing TACAN navigation. The first flight of a complete GPS system is planned for 1999.

In addition to modifying the Orbiter for Space Station operations, a self-rescue device was required to safely conduct Space Station extravehicular activity. Production of SAFER (Simplified Aid for Extravehicular Rescue) was initiated in FY 1995. SAFER will consist of a small propulsive backpack to be worn by each NASA-suited EVA crew member during all periods when the Orbiter is docked to structure (e.g., spacewalking from the Space Station or the Mir complex) when rescue of an inadvertently detached EVA crew member cannot be guaranteed. Currently during spacewalks from the Shuttle, EVA crew members are always tethered to prevent them from becoming separated. If an EVA crew member becomes inadvertently untethered, the Space Shuttle can easily fly to the rescue. However, the Mir and the Space Station will not be maneuverable enough to rescue an detached crew member, therefore, an autonomous self-rescue device must be provided. The SAFER unit provides the best overall self-rescue capability. Five SAFER flight units will be produced and fabricated along with two ground tests and training units. Fabrication of the SAFER units will be accomplished at JSC. The first operational use of SAFER is scheduled to be performed on a Space Shuttle-Mir docking flight STS-86/Mir-07 in FY 1997.

**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; and full inspection capability by design. 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 are dedicated to expand existing safety margins and reduce operational costs. Significant progress was made once the bearings were tested, accepted and introduced into the ATP HPOTP, testing proceeded successfully with completion of certification testing and first flight was accomplished in FY 1995. Throughout FY 1996, the ATP HPFTP experienced several problems during testing relating to alpha frequency vibrations occurring inside the turbopump assembly. The magnitude of these vibrations have been improved but this problem has eluded our efforts to eliminate in FY 1996. Design improvements and development testing to improve this condition will continue in FY 1997. The high pressure fuel turbopump, restarted during FY 1995, is scheduled for completion and first flight in FY 1998.

The SSME powerhead is the structural backbone of the engine, connecting the two pre-burners powering the high pressure turbopumps to the main propellant injector. The powerhead is the attach point for the high pressure turbopumps and the Main Combustion Chamber (MCC) and is also the duct for routing turbine discharge gas back to the main injector. The new Phase 11+ Powerhead will result in improved hot gas flow path characteristics from the high pressure fuel turbine to the main injector lox posts. Static and dynamic flow characteristics are improved throughout the hot gas flow path. The Phase 11+ Powerhead also reduced the number of welds, improving producibility and reliability.

The heat exchanger, mounted in the oxidizer side of the powerhead, uses the hot (800 - 900 degrees F) hydrogen-rich 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 of the tube.

The Large Throat Main Combustion Chamber (LTMCC) development will result 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 and an accompanying reduction in hot gas wall thickness. Hot gas wall temperatures are significantly reduced increasing chamber life. The LTMCC design also incorporates new fabrication techniques to reduce the number of critical welds and improve the producibility of the chamber. Development on the powerhead, heat exchanger and LTMCC is all being performed under contract with the Rocketdyne division of the Boeing North American Corporation.

The "block" change concept for incorporating changes into the main engine was introduced and baselined during FY 1994. The Phase 11+ 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 II is scheduled to be flown in early FY 1998 and consists of the Large Throat Main Combustion Chamber and the high pressure fuel turbopump. 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 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 are essential to improving the reliability of the Space Shuttle's launch capability.

The SLWT program is a result of **NASA's** desire to enhance the payload capability of the Space Shuttle to support the Space Station Program. In FY 1996, the verification testing of the Aluminum Lithium Test Article (ALTA) was successfully completed. This test demonstrated the capability of the liquid hydrogen barrel section of the SLWT to withstand flight loads with sufficient margin. During FY 1997, the SLWT will undergo final assembly and proof testing in preparation for delivery to KSC in September 1997. First flight is planned for December 1997.

**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 survivability 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.

The new Mission Control Center (MCC),completed in FY 1995 and supporting mission operations for all flights thereafter, has improved console operations and comniunication equipment as well as new data processing and distribution systems. Critical reliability required for the longer integrated simulations will be substantially improved with these replacements. Also, associated maintenance costs are reduced due to fewer computer breakdowns.

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 will replace 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 1999.

A cable plant upgrade at KSC has been initiated to replace the miles of cables which support a wide variety of Space Shuttle facilities. Many of these cables were installed in the 1960s and are suffering from corrosion and increasing failure rates. Replacement will reduce the potential for disruption to critical Space Shuttle operations as well as have a direct maintenance benefit. This activity will reduce the possibility of launch delays, increase communication system spares availability, and enhance

the reliability of data, instrumentation, voice, and video communications. This upgrade will replace the wide-band distribution system and the lead/antimony sheath cables with fiber optics and plastic sheath, gel-filled cable. In addition, many field terminals will be replaced or upgraded. Obsolete cable systems will also be replaced with current technology. The upgrade should be complete in late FY 1998.

A launch processing system control, checkout and monitoring system study is underway to assess the best system architecture for the program given the MCC upgrade and advancements in technology. In order to meet the needs of the next century a new launch processing system is required. The current study will provide options as to the best approach to bring forward for approval as a Phase II or III upgrade.

The Day-of-Launch-I-Load Update System, Version 2 (DOLILU-II) is designed to reduce flight and mission preparation costs while maintaining high launch probability for all mission profiles. Current first stage mission designs, baselined months before the flight, are replaced with a design built, assessed and uplinked to the vehicle on the day of launch. The system builds new first stage steering commands based on upper level winds measured four hours prior to launch time. Additional processors assess the new trajectory against system constraints to ensure mission safety. The system replaces months of preflight development and assessment of first stage flight designs. The DOLILU-II will also contribute to the ability of the Space Shuttle to launch within the five-minute window required for operations with the Space Station.

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.

**Construction of Facilities (CoF)**

FY 1996 CoF funding was concentrated on KSC facilities. The new Chemical Analysis Facility replaces the existing facility which is overcrowded and is in non-compliance with OSHA fire safety standards. The existing Space Shuttle Main Engine shop will be replaced by an addition to Orbiter Processing Building 3. Finally, there will be an upgrading of the fire protection pumps, motors, and diesels serving Launch Pads A and B fire protection system.

FY 1997 CoF funding is for facilities at KSC, MAF, and SSC. At KSC, there are two projects which are both at Launch Complex Pad B - the replacement of Pad B chiller system and the restoration of the Fixed Support Structure Elevator System. Both systems are over 25 years old and are past their economic life expectancy. These systems are part of a critical path for launch criteria assurance. At MAF, the rehabilitation and modification of the 480-volt electrical system are necessary to protect critical manufacturing operations in the final assembly and major weld areas for the manufacturing of the External Tank (ET). At SSC, the restoration of the High Pressure Industrial Water Plant will include the overhaul of three diesel engines for the deluge water system and two diesel engines for the electrical generation system. These engines drive the water pumps and electrical generators that provide cooling water and reliable power for all three SSME test stands for flight certification and development testing.

FY 1998 CoF will provide for improvements for facilities at **KSC** and MAF. At MAF, this project is phase II of IV to rehabilitate the 480-volt electrical distribution system that is critical to the manufacturing of the external tank. At KSC, one project will be restoring the walls and ceiling that provides a controlled environment to perform pre-flight services of Space Shuttle hardware at Pad A/LC-39 Payload Change-Out Room (PCR). The other project at **KSC** will restore the concrete surfaces and slope of Pad A/LC-39 structure. For additional details on these projects, please refer to the Mission Support - Construction of **Facilities** budget.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SHUTTLE OPERATIONS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Orbiter and integration | 521,000 | 516,600 | 463,100 |
| (Orbiter) | (378,500) | (375,400) | (356,100) |
| (System integration) | (142,500) | (141,200) | (107,000) |
| Propulsion | 1,061,500 | 1,098,700 | 1,136,900 |
| (External tank) | (327,500) | (339,000) | (359,700) |
| (Space shuttle main engine) | (185,000) | (182,300) | (184,900) |
| (Reusable solid rocket motor) | (395,700) | (427,000) | (434,600) |
| (Solid rocket booster) | (153,300) | (150,400) | (157,700) |
| Mission and launch operations | 902,900 | 899,600 | 894,400 |
| (Launch and landing operations) | (544,000) | (609,900) | (605,300) |
| (Mission and crew operations) | (358,900) | (289,700) | (289,100) |
| Total | 2,485,400 | 2,514,900 | 2,494,400 |

### 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 are subject to revision as changes to the manifest occur. The FY 1997 planned standard service reimbursements total $18.8 million, with $7.0 million in reimbursements assumed for FY 1998, which offset the budget for the Space Shuttle, and have been assumed in the budget request.

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 almost one-half of the Operations budget. As development items are completed, additional effort will be transitioned into SFOC.

## 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:
(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) 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
(5) The sustaining engineering associated with the Orbiter vehicles.

The major contractors for these Orbiter activities are United Space Alliance for operations: Boeing North American for External Tank disconnects and Orbiter sustaining engineering: and Hamilton Standard and Boeing for flight crew equipment processing.

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 will begin delivering Super Lightweight Tanks in support of the performance enhancement goal required by the Space Station in FY 1997. 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 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 North American Corporation, 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.

USBI, Inc. is the prime contractor on the SRB and conducts SRB retrieval, refurbishment and processing at KSC. USBI is in the process of consolidating their workforce at Kennedy Space Center from Huntsville, Alabama, and plans to complete the transition in FY 1997.

The Reusable Solid Rocket Motor (RSRM) project includes:

(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.

Thiokol of Brigham City, Utah is the prime contractor for this effort.

**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, as well as procurement of liquid propellants and gases for launch and base support. It also provides for support to landing operations at KSC (primary), DFRC (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 central data subsystem, which supports Space Shuttle processing as an on-line element of the launch processing 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 includes 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 US Alliance. 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). With the exception of 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 includes maintenance and operations of aircraft needed for flight training and crew proficiency requirements. Other support requirements are also provided for in this budget, including engineering tasks at JSC 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.

## PROGRAM GOALS

The goal of Space Shuttle Operations is to provide safe, reliable, and effective access to space. Space Shuttle operations are manifested at a planned rate of seven flights per year from FY 1997 through FY 1998. For FY 1999 through 2000, the flight rate is eight per year, with seven flights per year thereafter.

## STRATEGY FOR ACHIEVING GOALS

The Space Shuttle program is aggressively continuing to reduce the cost of operations. 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 (USA) was awarded the Space Flight Operations Contract (SFOC) on September 28, 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 US Alliance 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. All transitions will be completed in FY 2000. The reasons for this phased approach are two-fold:

1. The ongoing major development projects (e.g. SLWT, MEDS, ATP, etc.) 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 insure 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 operation, is responsible for (a) surveillance and audit to ensure compliance with SFOC requirements, and (b) internal NASA functions. Further, NASA will retain 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 process/controls necessary to ensure compliance with contract requirements and to sign a certification of flight readiness (CoFR) to that effect for each flight.

## MEASURES OF PERFORMANCE

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.

| Operations Metrics | FY 1996 Revised Plan | FY 1996 Actual | FY 1997 Plan | FY 1997 Current | FY 1998 Plan |
|---|---|---|---|---|---|
| Number of Space Shuttle Flights | 7 | 8 | 7 | 7 | 7 |
| Shuttle Operations Workforce (Prime Contractors)* | 16,707 | 16,707 | 15,961 | 16,519 | 16,478 |
| Space Shuttle Processing Overtime Required | 3% | 3% | 3% | 3% | 3% |
| Number of Days On-orbit | 90 | 94 | 80 | 84 | 76 |
| Number of Primary Payloads Flown | 12 | 12 | 9 | 9 | 8 |

* The contractor workforce data have been modified to include indirect, as well as direct contract workyears, which accounts for the variances in actuals and plans.

Space Shuttle Missions and Primary Payloads

| FY 1996 | | Plan | Actual |
|---|---|---|---|
| STS-73/Columbia | United States Microgravity Laboratory (USML-2) | September 1995 | October 1995 |
| STS-74/Atlantis | Russian Space Station Mir (Mir-2) | October 1995 | November 1995 |
| STS-72/Endeavour | SFU Retrieval/OAST-Flyer Deployment | November 1995 | January 1996 |
| STS-75/Columbia | Tether Satellite System Reflight (TSS-1R)/USMP-3 | February 1996 | February 1996 |
| STS-76/Atlantis | Russian Space Station Mir (Mir-3) | March 1996 | March 1996 |
| STS-77/Endeavour | Spacehab-4 | May 1996 | May 1996 |
| STS-78/Columbia | Life/Microgravity Sciences (LMS-1) | June 1996 | June 1996 |
| STS-79/Atlantis | Russian Space Station Mir (Mir-4) | August 1996 | September 1996 |
| **FY 1997** | | **Plan/Revised** | **Actual** |
| STS-80/Columbia | Wake Shield Facility-3 (WSF-3)/OREFUS-SPAS-02 | November 1996 | November 1996 |
| STS-81/Atlantis | Russian Space Station Mir (Mir-5)/Spacehab | December 1996 | January 1997 |
| STS-82/Discovery | Hubble Space Telescope Servicing Mission (MST SM-02) | February 1997 | |
| STS-83/Columbia | Microgravity Science Laboratory (MSL-1) | March 1997 | |
| STS-84/Atlantis | Russian Space Station Mir (Mir-6)/Spacehab | May 1997 | |
| STS-85/Discovery | Japan Manipulator Flight Demonstration/CRISTA-SPAS-02 | July 1997 | |
| STS-86/Atlantis | Space Station Mir (Mir-7) | September 1997 | |
| **FY 1998** | | **Plan** | |
| STS-87/Columbia | Microgravity Payload (USMP-04)/Spartan 201-04 | October 1997 | |
| STS-88/Endeavour | Space Station #1 (Node 1)(ISS-01-2A) | December 1997 | |
| STS-89/Endeavour | Russian Space Station Mir (Mir-8)/Spacehab | January 1998 | |

| | | |
|---|---|---|
| STS-90/Columbia | Neurolab | March 1998 |
| STS-91/Discovery | Russian Space Station Mir (Mir-9)/Spacehab | May 1998 |
| STS-92/Endeavour | Space Station #2 (ITSZi) (ISS-02-3A) | July 1998 |
| STS-93/Columbia | AXAF | August 1998 |

* Technical and weather-related problems caused the USML-2 launch to slip from FY 1995 to FY 1996.

In FY 1996, 50 U.S. crew members lived and worked in orbit for a total of 797 days, including time spent by an American astronaut aboard Mir. 42 crew members will fly 867 crew days in FY 1997 and 649 crew days are planned for in FY 1998.

To supplement the network of management reviews and government oversight functions, NASA continues to seek specific objective measurements for overall performance of the Space Shuttle program. In order to permit rapid review by the program director and program managers, the Space Shuttle program has devised a series of "stoplight" metrics, 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, Space Shuttle processing monthly mishaps, Orbiter systems and Line Replaceable Unit (LRU) problem reports, Space Shuttle processing contract overtime percentage, and Kennedy Space Center (KSC) quality surveillance error rate. The Space Shuttle program also tracks its launch history, monitoring the number of liftoff attempts per mission and characterizing any delays or scrubs as technical, weather or operational-related reasons.

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the Space Shuttle launched eight flights successfully including three flights to the Russian Mir Space Station. Additional flights deployed the Tether Satellite System, conducted a USMP mission and flew two Spacelab missions. The Japanese Space Flyer Unit was retrieved and many science and commercial development experiments were conducted in conjunction with the fourth Spacehab mission.

At the end of FY 1996, United Space Alliance (USA) was awarded the Space Flight Operations Contract (SFOC) on September 28, 1996. as the Space Shuttle single prime contractor. This begins Phase I of the operations consolidation wherein the major ground and flight operations work done today by Lockheed Martin and Boeing North American will be consolidated into a single program contract. This also initiates an approximately two-year transition of civil service from their current roles in project management and oversight to providing, on behalf of the Space Shuttle Program Manager, insight into the prime contractor's activities through audits, surveillance, assurance, and independent assessments of any problems or anomalies which are unique or have not been previously addressed (i.e., "out-of-family").

The seven flights manifested for FY 1997 include a Wake Shield experiment which was successfully flown in November 1996, and three more resupply flights to the Russian Space Station Mir. The Space Shuttle will make a second servicing visit to the Hubble Space Telescope in February 1997 replacing two current science instruments with "second generation" instruments and refurbishing some telescope support system components. The Space Shuttle will also support a development flight test of

components to be part of the Japanese Experiment module on the International Space Station. The Microgravity Science Laboratory mission (MSL) will study protein crystal growth. combustion, and material science experiments.

Seven flights will be flown during FY 1998, including two International Space Station assembly flights. In addition the last Spacelab mission (NEUROLAB) will be flown, in which the Space Shuttle crew will investigate the effects of weightlessness on neurological processes using both human and animal specimens. Another flight will deploy the Advanced X-Ray Astrophysics Facility *(AXAF)*.Two Spacehab flights during FY 1998 to the Mir Space Station are also manifested. Another mission includes a Microgravity payload package of experiments in the Orbiter cargo bay and a SPARTAN X-ray astronomy experiment using a retrievable free flyer.

Payload and
Utilization Operations

# HUMAN SPACE FLIGHT

## FISCAL YEAR 1998 ESTIMATES

## BUDGET SUMMARY

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

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | (Thousands of Dollars) | | | |
| Spacelab | 86,700 | 50,300 | 14,200 | HSF 4-3 |
| Tethered satellite system | 1,800 | -- | -- | HSF 4-7 |
| Payload processing and support | 40,600 | 41,700 | 51,600 | HSF 4-9 |
| Advanced projects | 24,200 | 34,700 | 58,700 | HSF 4-12 |
| Engineering and technical base | 169,700 | 148,600 | 102,900 | HSF 4-17 |
| Total | 323.000 | 275,300 | 227.400 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | 96,400 | 90,700 | 98,700 | |
| Kennedy Space Center | 88,600 | 72,500 | 58,900 | |
| Marshall Space Flight Center | 118,300 | 96,300 | 53,800 | |
| Stennis Space Center | 1,600 | 1,700 | 1,400 | |
| Langley Research Center | 300 | 300 | 500 | |
| Goddard Space Flight Center | 9,500 | 7,300 | 7,600 | |
| Headquarters | 8,300 | 6,500 | 6,500 | |
| Total | 323,000 | 275,300 | 227,400 | |

## PROGRAM GOALS

The primary goals of the Payload and Utilization Operations are to support the processing and flight of shuttle payloads, to ensure maximum return on the research investment, to reduce operations costs, to continue to implement flight and ground systems improvements, and to support strategic investments in advanced technology needed to meet future requirements.

## STRATEGY FOR ACHIEVING GOALS

The principal areas of activity in Payload and Utilization Operations include the operation of the Spacelab systems; cooperative reflight of the U.S./Italian Tethered Satellite System (TSS); Payload Operations for accommodating NASA payloads; Advanced Projects; and the preservation of an Engineering and Technical Base (ETB) capability at the human space flight centers. The activities of these programs are accomplished by civil service and contractor personnel. Over the past several years, NASA has been extremely successful in reducing processing time and error rates while increasing customer satisfaction and controlling cost. NASA will continue to implement operational efficiencies gained to date, plus assume additional efficiencies from elimination of duplicative activities, and from accepting minor risk increases by eliminating some testing and analysis during payload processing. Workforce reductions achieved to date have not impacted schedule time and the FY 1998 strategy includes plans to further reduce the workforce while maintaining or continuing to improve customer satisfaction.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACELAB

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Spacelab ..... | 86,700 | 50,300 | 14,200 |

### PROGRAM GOALS

Spacelab is a versatile, reusable, cost-effective observatory and laboratory facility located in the Space Shuttle payload bay. Spacelab supports a wide variety of science and technology development experiments which are developed by the utilizing programs within NASA and other external organizations. Spacelab serves as both an observatory and a laboratory, giving scientists the opportunity to conduct a large variety of scientific experiments in the unique environment of space.

### STRATEGY FOR ACHIEVING GOALS

Ten foreign nations, including nine members of the European Space Agency (ESA),participated in the joint Spacelab development program with NASA. The ESA designed, developed, manufactured and delivered the first set of Spacelab hardware which consisted of a pressurized module, five pallets, subsystem support hardware (e.g. igloo, Instrument Pointing Subsystem (IPS),racks, avionics, computers) and much of the ground support hardware and flight and ground software.

Spacelab is configured within the orbiter bay in numerous ways to accommodate scientific experiments in the unique environment of space. "Hands on" experiments requiring astronaut participation use the pressurized module configuration. Experiments not requiring a pressurized environment, or requiring visual access to space, use the unpressurized pallet configuration. The module is pressurized and thermally-controlled to enable astronauts to work in a "shirt sleeve" environment. Easy crew access from the orbiter middeck to the module is enabled by the Spacelab tunnel. Module missions largely consist of life and microgravity sciences experiments.

Spacelab pallet missions are designed to accommodate up to five pallets in the orbiter bay, depending on the experiment requirements. In the event the experiment requires the use of the Spacelab computers and other avionics hardware which must be protected from the space environment, the igloo is used to house the hardware and is flown as an attachment to the pallet. Other pallet configurations include the Spacelab pallet system (SPS). One configuration supports missions requiring the use of the Spacelab computer system and pallet in a mixed cargo configuration (i.e., more than one major payload flown in the orbiter bay rather than a single major payload flown using the igloo subsystem).

Spacelab operations support is comprised of mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, systems operation support, payload operations control support, payload processing, logistical support and sustaining engineering. Support software and procedures development, testing, and training activities are also included in NASA's funding request. The Spacelab operations cycle is repeated with each Spacelab flight, but with a different payload complement. This cycle consists of two processing integration steps. Spacelab Level IV processing performs the integration and checkout of the experiment equipment with individual experiment mounting elements like racks, rack sets, and pallet segments, and is funded by the payload sponsor. This activity is normally performed at the Kennedy Space Center (KSC)but is not part of the Spacelab operations budget. Spacelab Level III/II processing then combines and integrates all experiment mounting elements such as racks, rack sets and pallet segments, which have the experiment equipment already installed and ready for checkout with the Spacelab software. This processing activity is also performed at KSC and is funded under the Spacelab budget.

Spacelab operations also funds smaller secondary payloads like the Get-Away Specials (GAS) and Hitchhiker payloads. The GAS payloads are research experiments which are flown in standard canisters that 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 **138** 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 is supported by a contract with McDonnell-Douglas. Physical payload integration and processing is the responsibility of the Payload Management and Operations Office at the KSC, and is also supported by a contract with McDonnell-Douglas.

Another item funded in Spacelab operations 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.

The last Spacelab flight is scheduled for early **1998,** with the advent of the more permanent science laboratory flown by the International Space Station (ISS). In FY **1998,** Spacelab operations funding for GAS, Hitchhiker payloads and the FSS will be transferred to the Payload Processing and Support budget.

## MEASURES OF PERFORMANCE

| Spacelab Missions | plan | Actual |
|---|---|---|
| United States Microgravity Laboratory (USML-2) | September 1995 | October 1995 |
| Tether Satellite System Reflight (TSS-1R) | February 1996 | February 1996 |
| United States Microgravity Payload (USMP-3) | February 1996 | February 1996 |
| Life/Microgravity Sciences (LMS-1) | June 1996 | June 1996 |
| Microgravity Science Laboratory (MSL-1) | March 1997 | |
| United States Microgravity Payload (USMP-4) | October 1997 | |
| Space Life Sciences Laboratory-4 (Neurolab) | March 1998 | |

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| Flight Hardware Utilized | plan | Actual | plan | Revised | plan |
| Long Module | 1 | 2 | 1 | 1 | 1 |
| Multi-Purpose Experiment Support Structures (MPESS) | 1 | 1 | | | 1 |
| Pallets Plus MPESS | 2 | 1 | | | |
| Hitchhiker Experiments | 9 | 9 | 11 | 14 | 5 |
| Get Away Special Payloads | 15 | 15 | TBD | 2+TBD | 2+TBD |
| **Contractor Workforce** | | | | | |
| KSC (McDonnell-Douglas) | 254 | 240 | 253 | 228 | 73 |
| MSFC (McDonnell-Douglas) | 192 | 165 | 160 | 158 | 62 |

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the Spacelab program flew the following manifested missions: United States Microgravity Laboratory (USML-2) module mission, the Tether Satellite System Reflight (TSS-1R), United States Microgravity Payload (USMP-3), the Life and Microgravity Sciences (LMS) module mission, fifteen GAS payloads and nine Hitchhiker experiments.

Regarding FY 1997 activities, the Spacelab program will integrate and process Spacelab missions consistent with the Shuttle manifest including the Microgravity Sciences Laboratory (MSL-1) mission, as well as 14 Hitchhiker payloads and several GAS payloads. The mission to reservice the Hubble Space Telescope (HST SM-2) will utilize the flight support system (FSS). Efforts will be increased during the fiscal year to prepare for the Spacelab program phase-down (excluding the Hitchhiker, GAS and FSS programs), hardware/software disposition, final program flight in March 1998 and closing of the high bay in the Operations and Checkout facility presently projected for late FY 1998.

In FY 1998, the Spacelab program will process and integrate USMP-4 mission and the Neurolab module mission. Following the Neurolab mission, the final Spacelab program phasedown will occur, including disposition of hardware and software and closing the high bay in the Operations and Checkout facility. Because the Spacelab program is being terminated in FY 1998, the Hitchhiker, GAS and FSS programs are being transferred to the Payload Processing and Support program. In FY 1998 and subsequent years, significant reductions in both laboratory support and civil service workforce will occur from discontinuing the Spacelab program.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### TETHERED SATELLITE SYSTEM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Tethered satellite system reflight | 1,800 | -- | -- |

### PROGRAM GOALS

The goal of the Tethered satellite system reflight (TSS-1R) program is to study the electro-dynamics behavior of the satellite-tether-orbiter system as it interacts with the charged particles and electric and magnetic fields within the Ionosphere, and to complete verification of the capability and utility of a Space Shuttle-based tethered satellite system (TSS).

### STRATEGY FOR ACHIEVING GOALS

The TSS was a cooperative program with Italy to provide a reusable space facility that would conduct space experiments at distances up to 100 kilometers from the Space Shuttle Orbiter while being held in a fixed position relative to the Orbiter. During the demonstration mission flown in August 1992, the TSS verified its capability to provide a dynamically stable research facility, but a mechanical interference in the deployment system prevented full deployment of the tether and satellite and completion of the science mission. In response to an Italian Space Agency request to refly the mission, NASA conducted a reflight study, including an independent assessment of NASA's future use of tethered satellites. The study concluded that a reflight mission could be readily accomplished and recommended several improvements to enhance the probability of success. The independent assessment identified a number of significant and unique science and engineering objectives which can be accomplished using tethered satellites, and urged the continued development and utilization of the tethered technology. NASA agreed to refly the TSS-1 mission in February 1996.

NASA was responsible for overall program management, systems engineering and integration, orbiter integration, ground and flight operations, development of the deployment mechanism and provision of the non-European instruments (Office of Space Science funded). NASA made substantial cost reductions in FY 1995 and FY 1996 by using in-house Marshall Space Flight Center personnel to perform the TSS-1R integration and operations. Italy was responsible for the design and development of the satellite and the European instruments flown on the joint mission. The United States Air Force sponsored one of the TSS-1R investigations.

**MEASURES OF PERFORMANCE**

| | plan | Actual |
|---|---|---|
| Independent assessment of mission readiness | 1st Qtr 1996 | 4th Qtr 1995 |
| Launch TSS-1R | February 1996 | February 1996 |
| De-integrate TSS-1R | April 1996 | June 1996 |
| Post Mission Report | May 1996 | August 1996 |
| Complete Science Data Analysis | June 1997 | |

**ACCOMPLISHMENTS AND PLANS**

In FY 1996, the TSS-1R program completed integrated mission simulations, conducted an end-to-end communications test of the flight operations configuration, installed the payload in the Shuttle, and held flight readiness reviews. The TSS-1R mission was launched on STS-75 in February 1996. After being deployed to a distance of 19.7 kilometers, the tether broke and the satellite was lost. *An* independent review panel investigated the in-flight failure of the tether system and found the tether failed due to electrical arcing between the tether and deployer causing the burning and subsequent failure of the tether. Despite the incident, data gathered prior to the failure is expected to accomplish a majority of the science objectives. After completion of the TSS-1R mission, the remaining hardware was de-integrated and project phase-out began. Activity planned for completion in FY 1997 includes mission and science data analysis, hardware storage and decommissioning, future mission studies in accordance with the NASA/Italian MOU, and documentation archiving.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### PAYLOAD PROCESSING AND SUPPORT

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Payload processing and support | 40,600 | 41,700 | 51,600 |

### PROGRAM GOALS

The primary goal for payload processing and support is to provide the capability 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 processing 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. Funding from additional realized operational savings was transferred to Advanced Projects for the X-38 program in FY 1997 and to Engineering and Technical Base for Advanced Space Transportation Program requirements in FY 1998. Due to the termination of the Spacelab program in FY 1998, the Hitchhiker, Get Away Special (GAS) and Flight Support System (FSS)program will become part of the Payload Processing and Support program in FY 1998.

### MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| Missions Supported | plan | Actual | plan | Revised | |
| Space Shuttle Missions | 7 | 8 | 7 | 7 | 7 |
| Spacelab Payloads | 4 | 4 | 1 | 1 | 2 |
| Hitchhiker Experiments | 9 | 9 | 11 | 14 | 5 |
| Get-Away Special Payloads | 15 | 15 | TBD | 2+TBD | 2+TBD |
| Mir Missions | 3 | 3 | 3 | 3 | 2 |
| Other Major Payloads | 4 | 4 | 5 | 5 | 5 |
| Other Secondary Payloads | 2 | 2 | 1 | | |
| Expendable Launch Payloads | 9 | 8 | 7 | 10 | 8 |
| | | | | | |
| Number of Pavload Facilities Operating at KSC | 6 | 6 | 6 | 6 | 6 |
| KSC Pavload Ground Operations (PGOC) Workforce | 362 | 361 | 359 | 360 | 360 |

## ACCOMPLISHMENTS AND PLANS

The FY 1996 funding provided payload processing and support for eight Space Shuttle missions, as well as the necessary customer payload processing facilities and support for 37 major and secondary payloads. Among the payloads processed in FY 1996 include United States Microgravity Laboratory (USML-2),three Shuttle Mir missions (S/MM-2, 3 and 4), Space Flyer Unit Retrieval (SFU-RETR), Tethered Satellite System Reflight (TSS-1R), United States Microgravity Payload (USMP-3), SPARTAN 207/IAE, OAST FLYER, Spacehab-4, and Life and Microgravity Spacelab (LMS). Payload processing facility support was provided to ELV payloads such as Near Earth Asteroid Rendezvous (NEAR),Solar Heliospheric Observatory (SOHO),and X-ray Timing Explorer (XTE). These payloads are provided by American industries and universities, and also in cooperation with our international partners. The reflight of the Italian Tethered Space Satellite (TSS-1R) was a major payload involving international cooperation. Work was completed on the refurbishment of the instrument and control system and the environmental control system of the payload canister and transporter (used for transporting payloads at KSC). Consistent with the Agency's reduction of its infrastructure, NASA transferred the Cape Canaveral Air Force Station Hangar AO facility to the Air Force in January 1996.

In FY 1997, Payload Processing and Support will furnish launch and landing payload support for seven Shuttle missions, as well as payload processing facilities and support for 25 major and secondary payloads. The payloads to be processed in FY 1997 include Orfeus-Spas-2, Wake Shield Facility (WSF-3), Microgravity Science Laboratory (MSL-1), Shuttle Mir missions ((S/MM-5, 6 and 7), Hubble Space Telescope Servicing Mission (HST-SM-2), Crista-Spas-2 and Manipulator Flight Demonstration (MFD). Payload processing facility support will be provided to ELV payloads such as Advanced Composition Explorer (ACE),GOES-K, Mars Pathfinder, and Mars Global Surveyor (MGS).

In FY 1998, Payload Processing and Support will furnish launch and landing payload support for seven Shuttle missions, as well as payload processing facilities and support for 16 major and secondary payloads. Among the payloads to be processed are U.S. Microgravity payload (USMP-4), Neurolab, Spartan 201-04, Advanced X-Ray Astrophysics Facility (AXAF), Shuttle Mir missions ((S)MM-8, 9), Alpha Magnetic Spectrometer (AMS), two International Space Station (ISS-01-2A, 02-3A) assembly flights, and several secondary payloads. Payload processing facility support will be provided to ELV payloads such as New Millenium Deep Space-I and Cassini. The Hitchhiker, GAS, and FSS programs will be transferred to this budget from the discontinued Spacelab program.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### ADVANCED PROJECTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Advanced projects ..... | 24,200 | 34,700 | 58,700 |

### PROGRAM GOALS

The primary goals of the program are to mature technologies to enhance crew safety for the Space Shuttle and Space Station, to implement flight and ground systems improvements to substantially reduce cost of Space Flight operations, and to pursue advanced technology developments to meet future Human Space Flight requirements. Secondary goals of the program are to promote transfer of advanced technologies and to develop a fully capable, diverse and motivated workforce. The Advanced Projects activity includes five program elements: Advanced Development and Operations, Advanced Space Systems, Advanced Extravehicular Activity (EVA) Systems, Telerobotics Research and Technology, and the X-38 demonstration program.

### STRATEGY FOR ACHIEVING GOALS

The Advanced Development and Operations program supports projects which improve ground and flight operations of current and future Human Space Flight vehicles by identifying, advocating and demonstrating available technologies and processes which are more efficient, cost-effective, reliable, have dual use potential, and meet safety and performance requirements. The projects are developed to a prototype level to validate their objectives within three years. Successfully demonstrated projects are transitioned to an operational program for implementation and to private enterprise for commercial development.

Several Advanced Operations projects have been jointly funded, either in their development or commercialization, by other government agencies such as the Department of Energy, and the State of Florida, as well as by private industry, via cooperative agreements or Space Act Agreements. The Advanced Operations program places a high priority on leveraging its limited funds through partnerships with other fund sources, public and private, to achieve its goals.

The Advanced Space Systems program includes the Orbital Debris program and a series of flight demonstration experiments to validate critical advanced technologies in a relevant environment. The Orbital Debris effort supports projects which improve the safety of the Space Shuttle and the Space Station by measuring, modeling, and mitigating the orbital debris environment. In addition, the Orbital Debris activity includes an international cooperative program, jointly funded by the space agencies of Russia, Japan, China and the European Space Agency, which seeks to develop a common understanding of the debris environment. This program also develops common practices for protecting spacecraft and mitigating the orbital debris environment. The Flight Demonstration program identifies and demonstrates available technologies and processes which are efficient, cost-effective, reliable, and meet safety and performance requirements. Projects are matured to a protoflight level, utilizing existing carriers as

test beds for developing space flight hardware and operational processes to ensure their readiness to meet operational requirements. Flight demonstrations also includes training for young NASA engineers and managers with early "hands-on" flight hardware experience.

For safety reasons, a Crew Return Vehicle (CRV) is necessary for permanent human habitation of the International Space Station. The X-38 experimental vehicle is specifically designed to demonstrate the technologies and processes required to produce a CRV in a 'better, faster, cheaper" mode. Evaluation of the performance of the technologies **of** the X-38 systems are conducted through a series of ground, air, and space tests. Based on the U.S. Air Force/Martin-Marietta X-24A lifting body research vehicle, successful demonstration of the X-38 technologies will lead to a final CRV configuration for implementation on the International Space Station. Through cooperative arrangements which are under discussion with the European Space Agency, the DOD, and the Japanese Space Agency, NASA will also seek to find and develop commonality between the CRV and other space vehicles.

The primary goals of the Advanced EVA program are to perform the scientific research and engineering development needed to mature technologies that enhance EVA crew safety, reduce EVA operational cost and enhance capabilities to meet future space flight requirements. The Advanced EVA research and development program includes research and development to reduce the operational impact **of** decompression sickness, while increasing safety via better understanding of the science involved. The research and development roadmap includes tasks to address environmental protection, EVA mobility, electronics integration, and EVA system integration with other space systems. The Advanced EVA program is conducted using a mix of ground based simulation and flight testing to prove the development approach. After four years of ground-based research and development, the program concludes with a three-year task to demonstrate on-orbit the new EVA technologies from a systems point of view. The program actively seeks partnering with industry and other government agencies as well as transfer of technology into the program from outside sources to accomplish the needed technology development.

The Telerobotics Research and Technology program includes research and development of telerobotics technologies to improve crew efficiencies and capabilities for the Human Exploration and Development of Space, including the International Space Station and Space Shuttle. Telerobotics research includes areas such as EVA assistant, dexterous manipulators, sensing and processing, mobility systems, human interfaces, and other related telerobotics technologies. The telerobotics program is conducted through ground and flight research and demonstrations to prove the viability of each technology approach. The Telerobotics Research and Technology program was transferred to the Advanced Projects Office during FY 1997 from the former Office of Space Access and Technology.

## MEASURES OF PERFORMANCE

The success of the Advanced Projects activities has been, and will continue to be, measured by the success of its projects. Over 100 projects have been supported in the past six years, most of which have been successful in delivering products that enhance the efficiency and reduce the cost of ground and flight operations. Many of the advanced technologies incorporated in the new integrated Shuttle/Station Mission Control Center were developed in this program. These technologies are contributing to a significant reduction of Space Flight mission operations costs. The following events represent significant milestones in the successful completion of this program:

## Advanced Operations

| | |
|---|---|
| Migrate Mission Information System and Electronic Documentation System to the MCC<br>Plan: 1st Qtr FY 1996<br>Actual: 1st Qtr FY 1996 | Provides paperless documentation capability to the MCC and flight support offices at the Johnson Space Center, to remote payload support offices, and to the flight vehicle. Both tools are now in routine use in the MCC. |
| Deliver on-board training system for STS-76/Mir mission demonstration<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Demonstrates the capability to provide contingency and proficiency training for crews via laptop computer during long-duration missions. |
| Demonstrate Electronic Documentation System on-board STS-76/Mir<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Extends the "paperless" flight document capability now available in the Mission Control Center to the flight vehicle enabling more efficient document update during long-duration missions as well as reduced publication costs. |
| Complete Advanced Training "walk-in" virtual environment<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | Demonstrates state-of-the art training technique which could improve efficiency and reduce cost of total immersion training previously provided by simulators and water tanks. |

In the Orbital Debris activity, accurate measurements have been made of the orbital debris environment. Models have been developed to predict the changes in the environment as a function of time. Utilizing these measurements, flight rules, operational procedures, and new orbital debris protection systems have been developed and/or modified to improve/enhance safety during Shuttle and Space Station operations. To date, a total of 16 successful flight demonstrations have been flown. All of these demonstrations achieved their primary technical objectives. All of the flight demonstration projects that are currently under development have been manifested. Future milestones include:

**Advanced Space Systems**

| | |
|---|---|
| Static Feed Electrolyzer (SFE) Flight Demonstration Critical Design Review<br>Plan: 1st Qtr FY 1996<br>Revised: 3rd Qtr FY 1996 | This flight demonstration will validate the microgravity sensitivity of key SFE subsystem components on an integrated basis. *An* operational SFE would reduce the annual resupply weight for the International Space Station by 12,000 pounds with an associated reduction in logistics costs. The CDR was delayed in FY 1996 due to lack **of** final design maturity. |
| International Space Welding Experiment (ISWE) Cargo Integration Review<br>Plan: 1st Qtr FY 1997<br>Revised: Under Development | The ISWE will demonstrate the ability to perform contingency repairs to the International Space Station using an electron beam welding device developed by the Paton Institute in the Ukraine. |
| Orbital Debris Collector (ODC) Returned from Mir<br>Plan: 4th Qtr FY 1997 | The ODC is an experiment to collect *in-situ* samples of the micro debris environment from the orbit of the International Space Station to understand the sources of this debris and thus enabling effective steps to mitigate it. |
| Students for the Exploration and Development of Space Satellite (SEDSAT) Delivery to KSC<br>Plan: 4th Qtr FY 1997 | Delivery of SEDSAT satellite for testing and integration. |
| Students for the Exploration and Development of Space Satellite (SEDSAT) Launch<br>Plan: 4th Qtr FY 1997 | Deployment of SEDSAT as a DELTA II secondary payload. SEDSAT will serve as an amateur radio relay system and will collect multi-spectral remote sensing data. |
| SFE Flight Demonstration<br>Plan: 1st Qtr FY 1998<br>Revised: Under Development | This flight demonstration will verify the performance capability of the SFE subsystem in microgravity during the STS-87 mission. This flight demonstration was redirected at the request of Space Station. A new oxygen generation experiment is planned. |
| International Space Welding Experiment (ISWE) Flight Demonstration<br>Plan: 1st Qtr FY 1998<br>Revised: Under Development | The capability of the Ukrainian Universal Hardware to perform contingency repairs on the International Space Station will be demonstrated during the STS-87 Mission. The ISWE project has been recently demanifested to accommodate the reflight of the EVA Development Flight Test (EDFT) program on STS-87. *An* alternative flight manifest opportunity for ISWE is under review. |

| | |
|---|---|
| Atmospheric Test Program<br>Plan: 4th Qtr FY 1997 | Five atmospheric test flights of Vehicles 131 and 132 conducted to demonstrate full lifting body control and parafoil control systems. |
| Begin initial Space Vehicle (201) Construction<br>Plan: 4th Qtr FY 1997 | Construction of the first (201) space vehicle will be initiated. Primary structure (cabin and aft fuselage) will be fabricated, most subsystems installed and ready for integrated test, and some aeroshell panels with thermal protection system will be completed. |

**Advanced EVA Research and Development**

| | |
|---|---|
| Gloves ready for flight tests<br>Plan: 2nd Qtr FY 1997,<br>3rd Qtr FY 1998 &<br>3rd Qtr FY 1999 | Demonstrates on-orbit performance of gloves which incorporate increased mobility features and better thermal protection. |
| Soft space suit configuration hardware delivery<br>Plan: 2nd Qtr FY 1998 | Delivery of new soft space suit for testing. Soft suits hold potential of being lighter weight and easier to stow. |
| Soft space suit configuration comparison test delivery<br>Plan: 3rd Qtr FY 1998 | Demonstrates the amount of mobility that can be incorporated into a soft suit configuration. |
| Radiator ready for test<br>Plan: 3rd Qtr FY 1998 | Demonstrates on-orbit cooling using a radiator instead of water sublimation in the real thermal environment. |

**Telerobotics Research and Technology**

| | |
|---|---|
| Free-Flying Camera Robots for EVA<br>Plan: 4th Qtr FY 1997 | Implement upgrades to the existing Supplemental Camera and Maneuvering Platform (SCAMP) system. |
| Robotics Technologies for ISS Maintenance | |
| Plan: 2nd Qtr FY 1997 | Testing of remote surface inspection systems. |
| Plan: 4th Qtr FY 1997 | Evaluation of calibrated synthetic viewing. |
| Plan: 4th Qtr FY 1997 | Performance of robotic control technologies. |

## ACCOMPLISHMENTS AND PLANS

FY **1996** was a transition year for the Advanced Operations program. Four high-leverage tasks were completed. First, the Electronic Documentation Project completed certification testing, and transitioned operations to the Mission Control Center, extended its capabilities to other NASA Centers, and demonstrated its use on-board the Shuttle. Second, the Advanced Training Technologies (ATT) project demonstrated the capability to provide contingency and proficiency training in-orbit via laptop computer, and demonstrated a "walk-in" virtual environment to provide total immersion training now done in simulators and water tanks. One of the products of the ATT project was named NASA Invention of the Year for **1995,** and its project manager received the **1995** American Management Society award for outstanding technical management. Third, the Cooperating Expert Systems (COOPES)project completed development and certification of vehicle system monitoring expert systems and information sharing software tools for the Mission Control Center. The project received a Federal Leadership Award and a Space Act Award during FY **1995** for development of the Information Protocol. Fourth, the Conductive Polymer Coating Space Act Agreement received the final installment in its 3-year commercial development process. The corporate, university and government laboratory partners plan to complete testing of the coating and have it ready for market in **1998.** Beginning in FY **1997,** this successful program will be transitioned to the Space Shuttle program to help meet its cost reduction goals.

Also in **FY 1996,** an Advanced Development effort was initiated to mitigate risk for the future development of a crew return vehicle and other applications. Industry has been briefed on the X-38 program status and how the design of the Space Station CRV will be based on the design and technologies demonstrated on the space flight test articles of the X-38 program. **An** industry procurement competition for the operational Space Station CRV flight vehicle production is scheduled to take place in late FY **1997.** By pursuing a rapid prototype technology demonstration effort, the **X-38** program will validate critical technologies required to support the development of an operational Space Station CRV resulting in substantially reduced development costs for this capability, while providing a cost effective opportunity to validate technologies for other future space flight requirements. The X-38 project is an effort to reduce the cost of a crew return vehicle (CRV) for the International Space Station by developing and flight-testing critical technologies for the vehicle. The effort is an in-house, civil servant effort focused on design studies, computer analysis, subsystem component testing and limited in-flight demonstrations. The resulting operational CRV is to be produced by industry utilizing the technologies advanced by NASA. Particular emphasis is placed on technologies that have the potential to reduce design and operational costs for the vehicle. This activity will continue through FY **1999.**

The **X-38** program will continue to measure subsystem and system performance throughout FY **1997.** A key element of the plans include completion of the Atmospheric Test program in which two vehicles (131, **132)** will be drop-tested from a **B-52** to prove a mix of lifting body and parafoil systems and flight modes. Construction of the first space vehicle **(201)** will be nearly complete during FY **1998.** The Aft Fuselage, Outer Skin and Thermal Protection Systems (TPS) will be completed and the first de-orbit module will be delivered. Integrated testing of vehicle **201** will also begin in FY **1998.**

In the Advanced Space Systems program a total of **16** successful flight demonstrations have been conducted. Some examples of recent accomplishments follow:

The second phase (hardware development phase) of the International Space Welding Experiment (ISWE)with the Paton welding Institute (PWI) in Ukraine was successfully initiated. A phase 2 (hardware development) contract with PWI was negotiated for the delivery of two sets of universal hardware as well as a work station. Design and fabrication of the flight universal hardware and the work station were completed early in FY 1997. Delivery of the flight universal hardware occurred in FY 1996 and the flight workstation was delivered in early FY 1997.

The Orbital Debris program is directed at measuring the orbital debris environment, developing debris growth mitigation measures, and enhancing spacecraft protection and survivability techniques. Additional hours of observations of the debris environment were collected in FY 1996 using the Haystack Orbital Debris Radar bringing the total to over 5000 hours. Additional measurements of the environment were obtained from numerous Shuttle missions providing invaluable data on the nature **of** the micro-debris environment and its damage potential to manned spacecraft. The liquid metal mirror telescope was moved to Cloudcroft, New Mexico. Visual observations **of** debris particles as small as 10 centimeters in geostationary orbit are possible using this telescope. The Orbital Debris Radar Calibration Spheres (ODERACS-2)flight demonstration was flown on the Space Shuttle. ODERACS-2 successfully deployed three spheres and three dipoles which were used to calibrate the Haystack Orbital Debris Radar, optical telescopes and other radars used to characterized the orbital debris environment.

In FY 1997 and FY 1998, the Haystack Auxiliary Radar and the Haystack Radar will continue to monitor the orbital debris environment for the Space Station. Orbital debris will continue to focus on characterizing changes in the orbital debris environment as a function of time and on establishing measures for mitigation of debris growth trends. An international geostationary debris observing program will be initiated with participation from NASA, ESA, Russia, Japan, Australia, and other spacefaring nations. Work will begin on the design of an Extra Vehicular Activity (EVA)debris shield for protecting the Space Station crews when they are exposed to the debris environment during an EVA.

In FY 1997, Advanced Projects will support the AERcam/Sprint flight experiment, a robotic "flying eye" for visualization and inspection of science and Space Station payloads.

The Debris Capture experiment will be returned from the Mir station after approximately one year in orbit. Analysis will begin of the debris samples captured by the aero gel.

The ISWE flight demonstration will achieve launch readiness early in FY 1998, but a flight date aboard the Space Shuttle remains to be determined.

In FY 1997 and FY 1998, the Advanced EVA Research and Development program will start research to address the mechanisms which control decompression sickness in a zero gravity environment. Research into better protection for EVA operations in the space environment will also be initiated. The design efforts for space suits which are predominantly built with soft elements and a portable life support system which uses cryo oxygen will be initiated.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### ENGINEERING AND TECHNICAL BASE

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Engineering and technical base ..... | 169,700 | 148,600 | 102,900 |

**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 provides the underpinning of the Centers' performance of research and analysis and testing tasks, to solve present problems, and to reduce costs in developing programs, technologies, and materials.

**STRATEGY FOR ACHIEVING** GOALS

The Office of Space Flight (OSF) strives to sustain its institutional technical base and preserve **a** high degree of core capability and excellence. Since FY 1994 the four 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 in information resources management and contract streamlining. A prioritized core environment will be dedicated to multi-program labs and test facilities, associated systems, equipment, and a full range of skills capable of response to research, testing and simulation demands.

*As* the ETB budget is reduced, several activities will be continued to refine current business practices. Mandatory equipment repair and replacement will be reassessed. Software applications for multi-program analytical tools will be implemented. Strategy to better manage the NASA investment in information processing resources will include 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 component of the ETB strategy will be to provide a core capability for future human space flight endeavors with fewer resources. Future budget constraints dictate that new innovative processes be adopted to meet critical ETB core requirements, and that non-critical capabilities be streamlined or eliminated.

| ME OF ORMAN( | |
|---|---|
| Laboratory facilities (KSC) | Continuing Support for 22 labs for approximately 121 applied research projects. |
| Laboratory facilities (JSC) | Continuing support for science and engineering laboratories. |
| Laboratory facilities (MSFC) | Continuing support for approximately 50 core laboratory areas. |
| Propulsion Facility and Lab Facilities (WSTF) | Continuing provision **of** core environment to support customer base. |
| Information resource management (IRM) Five Year Investment Plan (MSFC)<br>Plan: 4th Qtr FY 1996<br>Revised: 4th Qtr FY 1997 | Consolidate ADP Operations of the other Field Centers to the supercomputer. Ames Research Center is in charge of the initiative. A draft schedule is currently being reviewed, but this will be an on-going effort through FY 1997. |
| NASA Minority University Research and Education Program at JSC, KSC, MSFC & SSC | Award education and research grants |

**ACCOMPLISHMENTS AND PLANS**

The institutional technical base accomplished numerous activities in FY 1996. At JSC, ETB funded the purchase of laboratory equipment and technicians, engineering workstations, calibration equipment and services, component fabrication, and Class VI computer maintenance and operations in support of the science and engineering laboratories and facilities at JSC. This ETB support ensures that JSC retains the capability to perform real-time mission analysis of flight anomalies and real-time and post-flight problem resolutions, as well as other science and engineering testing and analysis. In addition to laboratory support, ETB supports safety, reliability, and quality assurance (SR&QA) activities for the Space Shuttle and Space Station programs. JSC also continued to award ETB research grants to Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs).

At WSTF, FY 1996 ETB funding supported the propulsion testing facility and other laboratory infrastructure. Maintaining this core environment with ETB enabled WSTF to support a customer base with testing and evaluations of spacecraft materials, components, and propulsion systems for safe human exploration and utilization of space. It enabled WSTF to perform tasks for all NASA programs as well as other Government agencies and the aerospace and medical industry.

With ETB funding, the KSC supports a core environment for 22 laboratories and for 121 applied research projects. The ETB enables the KSC to eliminate potentially critical failures on the KSC fiber optic circuits and assists the Shuttle Launch Processing

System organization in understanding and properly using fiber optics for launch processing. The ETB supported upgrades to the LC-39 measurement system. The ETB also participated in the development of landing aids for a lightning warning and prediction system, as well as development of toxic vapor detectors and sensors to measure vapors from the Space Shuttle tile waterproofing compound. In addition, ETB supports KSC's Life Sciences tasks.

The MSFC allocation of ETB funds supports approximately 50 core laboratory areas. ETB support enables the Center'stechnical core capability to provide in-depth technical support for designs, developments, testing, mission operations and evaluation of Launch Vehicles, Space Transportation Systems, Space Stations, and Payloads. ETB enables MSFC to conduct research and development efforts related to advanced propulsion systems and spacecraft, as well as engineering design, systems engineering, systems integration, material and process engineering, physical science research, test and evaluation, data analysis and system simulations. As the NASA Center of Excellence in propulsion systems, in FY 1997, MSFC is continuing to support the Advanced Space Transportation Technology Program, whose ultimate objective is to make dramatic reductions in the cost of boosting payloads into low-Earth orbit. Funding in the amount of $12.0 million is identified to continue development of low-cost, small booster technologies and demonstration of rocket-based combined cycle (RBCC)propulsion hardware. Effort on low-cost small booster technologies will include avionics hardware, engine component hardware (injector, chamber, turbomachinery, valves, actuators, ducts and lines), test support and propellants for component testing. RBCC activities include test hardware fabrication, test support and propellants. Continuation of these activities after FY 1997 has been transferred to the Aeronautics and Space Technology program.

At SSC, ETB supports the SSC technical core laboratory operations, and will fund initial operations for the Component Test Facility (CTF) in FY 1997. CTF will play a central role in making the Stennis Space Center the Center of Excellence for propulsion testing. The ***SSC*** laboratories perform activities for the Space Shuttle program, reimbursable resident governmental agencies and the CTF test operations. The SSC core laboratory environment provides customers with gas and material analysis, non-destructive evaluations, standards and calibrations, environmental analysis, fluid component processing, maintenance and fabrication of welded structures and components, and machining and fabrication of mechanical structures and components. ,ETB also enables SSC to complete advanced planning studies involving cost trade presentations for future facility utilization and technology development tasks such as the seal configuration tester prototype. ETB also funds sensor development for engine health management and for spectral analysis.

The ETB program includes the institutional Safety and Mission Assurance (SRM&QA) contractor workforce performs space flight activities at JSC, WSTF, MSFC and KSC. This workforce includes highly skilled personnel who are charged with responsibility to conduct assessments of conformance to reliability and quality standards. In FY 1996, surveillance of design, manufacturing and testing of hardware and software was conducted to ensure compliance with NASA safety and mission assurance requirements. The ETB resources will support independent assessments of flight and test equipment and testing operations, including product assurance tasks for the International Space Station program (ISS). However, product assurance tasks and funding for the ISS will be transferred to the Office of Safety and Mission Assurance in FY 1998.

Information resource management (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 located at MSFC. Consolidation of user requirements and information technology plans were implemented at JSC, MSFC, SSC and Headquarters. The NASA Automated Data Processing (ADP) Consolidation Center (NACC) provides supercomputing capability for its customers for engineering and scientific computer-intensive applications 7 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.

The NACC supercomputing customers are from JSC and MSFC. 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 the past, supercomputing at both JSC and MSFC was funded through ETB at the individual Centers. The NACC supercomputing facility is funded through ETB and programmatic funding from the participating supercomputer customers beginning in FY 1996. During FY 1997, MSFC and JSC will continue to develop and process software applications under the new funding arrangements.

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), Other Minority Universities (OMU), Teacher/Faculty enhancement programs, and JSC University Research Program. MSFC awarded a total of 52 grants in FY 1996. Examples of awards granted include solution crystal growth in low gravity: organic fiber optic sensors; hydrazine solution disposal: atmospheric corrosion sensor: properties of ion beam deposits, and phytoalexins in plant disease.

In FY 1998, the ETB budget will continue to implement reductions resulting from the Agency's zero-base review. These reductions will result in 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 space flight institutional engineering support for future human space flight programs and the existing customer base. This assessment will focus on maintaining core support for design, development, test and evaluations, independent assessments, simulation, operations support, anomaly resolution, and systems engineering activities with reduced funding. The operation and maintenance of the CTF will be supported, as will a variety of research and engineering laboratories. FY 1998 funding is significantly reduced from previous years due to the transfer of the development of low-cost small booster technologies and demonstration of rocket-based combined cycle (RBCC) hardware to the Advanced Space Transportation Technology program: the transfer of the International Space Station independent assessment function to the Office of Safety and Mission Assurance; and other infrastructure reductions at the Human Space Flight Centers.

Science, Aeronautics
and Technology

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**SCIENCE, AERONAUTICS AND TECHNOLOGY**

**FISCAL *YEAR* 1998 ESTIMATES**

**AI TEMENT**

## 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 aeronautics and advanced space transportation technologies which 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.

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

Aeronautics and Space Transportation 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 effectivetelecommunications services in support of NASA's science and aeronautics programs, and to conduct NASA's Agencywide university, minority university, and elementary and secondary school programs.

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## SCIENCE. AERONAUTICS AND TECHNOLOGY

### FISCAL *YEAR* 1998 ESTIMATES
### (IN MILLIONS OF REAL *YEAR* DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| **SCIENCE, AERONAUTICS AND TECHNOLOGY** | **5,670.4** | 5,453.1 | **5.642.0** |
| SPACE SCIENCE | 2,175.9 | 1,969.3 | 2,043.8 |
| LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS | 304.2 | 243.7 | 214.2 |
| MISSION TO PLANET EARTH | 1,360.8 | 1,361.6 | 1,417.3 |
| AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY | 1,270.1 | 1,339.5 | 1,469.5 |
| MISSION COMMUNICATION SERVICES | 449.5 | 418.6 | 400.8 |
| ACADEMIC PROGRAMS | 109.9 | 120.4 | 96.4 |

## 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, [$5,762,100,000] *$5,642,000,000*, to remain available until September 30. [1998] 1999. [Chapter VII of Public Law, 104-6 is amended under the heading, "National Aeronautics and Space Administration" by replacing "September 30. 1997" with "September 30, 1998" and "1996" with "1997"]. Under the heading, "National Aeronautics Facilities," NASA, in Public Law 103-327, as amended, delete "September 30. 1998" and insert "September 30, 1999" delete "October 1, 1997" and insert "October 1, 1998".

For necessary expenses of certain space projects under development. 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 1998. $457,000,000; for fiscal year 1999, $504,900,000; for fiscal year 2000, $253,800,000; for fiscal year 2001, $149,700,000; and for fiscal year 2002, $25,800.000. (Departments of Veterans *Affairs* and Housing *and* Urban Development. and *Independent* Agencies Appropriations Acts, ***1997.1***

[For an additional amount for "Science. Aeronautics and Technology". $5,000,000, to remain available until September 30. 1998.1 (*Omnibus* Consolidated Appropriations Act. ***1997.)***

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## SCIENCE, AERONAUTICS AND TECHNOLOGY

### REIMBURSABLE SUMMARY
### (IN MILLIONS OF REAL YEAR DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| **SCIENCE, AERONAUTICS AND TECHNOLOGY** | **421.4** | **689.7** | **656.8** |
| SPACE SCIENCE | 90.4 | 105.5 | 88.0 |
| LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS | 0.9 | 0.9 | 0.8 |
| MISSION TO PLANET EARTH | 260.5 | 488.9 | 486.5 |
| AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY | 64.5 | 69.5 | 63.6 |
| MISSION COMMUNICATION SERVICES | 5.1 | 24.4 | 17.4 |
| ACADEMIC PROGRAMS | -- | 0.5 | 0.5 |

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## FISCAL YEAR 1998 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 | Lewis Research Center | Goddard Space Flight Center | Jet Propulsion Lab | Headquarters |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Science | 1996 | 2,175,900 | 3.600 | 5,100 | 356,200 | 0 | 94.400 | 0 | 8.600 | 23.200 | 764,800 | 753.900 | 166.100 |
| | 1997 | 1.969.300 | 3.600 | 9.000 | 307,900 | 0 | 71.000 | 0 | 9,000 | 27,400 | 842.000 | 655.300 | 44.100 |
| | 1998 | 2,043,800 | 4.100 | 9,800 | 202.000 | 0 | 79.400 | 0 | 15.100 | 26.400 | 901.700 | 717.300 | 88.000 |
| Life and Microgravity Sciences and Applications | 1996 | 304.200 | 72.900 | 11.200 | 67.300 | 0 | 28.900 | 0 | 4.100 | 53.300 | 1.300 | 13.600 | 51,600 |
| | 1997 | 243,700 | 38.100 | 7.200 | 49.000 | 0 | 26.300 | 0 | 2.700 | 41.000 | 22.200 | 16,700 | 40.500 |
| | 1998 | 214.200 | 37.700 | 6.400 | 45.800 | 0 | 21.500 | 0 | 2.400 | 37.700 | 27.800 | 13.800 | 21.100 |
| Mission to Planet Earth | 1996 | 1.360.800 | 100 | 4.900 | 4.200 | 17.200 | 38.100 | 5.100 | 27.000 | 68,400 | 922.400 | 68.600 | 204.800 |
| | 1997 | 1.361.600 | 0 | 4,700 | 5.400 | 66.200 | 8.200 | 19,000 | 42.500 | 16.300 | 991.300 | 97.200 | 110.800 |
| | 1998 | 1.417.300 | 0 | 6.600 | 4.000 | 16.200 | 5,500 | 18.700 | 30,600 | 36.000 | 1,067,600 | 103.100 | 129,000 |
| Aeronautical Research and Technology | 1996 | 865,900 | 0 | 0 | 5.008 | 0 | 203,388 | 62.575 | 312,647 | 247,677 | 7.044 | 2,292 | 25.269 |
| | 1997 | 844.200 | 0 | 0 | 3.856 | 0 | 186.560 | 55.487 | 319.753 | 245,055 | 7.995 | 1.781 | 23.713 |
| | 1998 | 920.100 | 0 | 0 | 3.865 | 0 | 220.349 | 72.594 | 344.040 | 249.171 | 4.129 | 2.160 | 23,792 |
| Advanced Space Transportation Technology | 1996 | 234.000 | 900 | 300 | 147,600 | 46.400 | 7.700 | 0 | 14,300 | 2.900 | 0 | 3.300 | 10.600 |
| | 1997 | 336.700 | 3.000 | 100 | 274,200 | 6.900 | 8.600 | 6.300 | 13,200 | 2.700 | 100 | 8,700 | 12.900 |
| | 1998 | 396.600 | 2.400 | 400 | 340.800 | 10,300 | 6.800 | 2.700 | 5.700 | 3.200 | 0 | 5,600 | 18.700 |
| Commercial Technology | 1996 | 170,200 | 24.300 | 5.700 | 23.200 | 4,000 | 14.100 | 4.800 | 20,500 | 20.300 | 29.500 | 2.800 | 21,000 |
| | 1997 | 158.600 | 17.800 | 6,500 | 30.900 | 4.100 | 15.600 | 4.300 | 20.700 | 22,100 | 27.000 | 2.200 | 7.400 |
| | 1998 | 152.800 | 17,600 | 6.800 | 34.900 | 4.400 | 15.100 | 4,800 | 18.600 | 19.500 | 25.900 | 1.700 | 3.500 |
| Total Aeronautics & Space Transportation Technology | 1996 | 1,270,100 | 25.200 | 6.000 | 175.808 | 50.400 | 225.188 | 67.375 | 347.447 | 270.877 | 36,544 | 8.392 | 56,869 |
| | 1997 | 1,339,500 | 20.800 | 6.600 | 308.956 | 11,000 | 210.760 | 66.087 | 353.653 | 269.855 | 35.095 | 12.681 | 44.013 |
| | 1998 | 1,469,500 | 20,000 | 7.200 | 379.565 | 14.700 | 242.249 | 80,094 | 368,340 | 271,871 | 30.029 | 9.460 | 45.992 |
| Mission Communication Services | 1996 | 449,500 | 0 | 0 | 3.000 | 0 | 0 | 13.900 | 0 | 10,100 | 228.515 | 190,172 | 3.813 |
| | 1997 | 418.600 | 8.200 | 0 | 1,300 | 0 | 0 | 15.000 | 0 | 9.800 | 194.800 | 185.700 | 3,800 |
| | 1998 | 400.800 | 0 | 0 | 2.100 | 0 | 0 | 14.500 | 0 | 10,000 | 202.800 | 169,000 | 2,400 |
| Academic Programs | 1996 | 109,900 | 2.169 | 1.134 | 3.344 | 1,467 | 4.247 | 322 | 2,991 | 2.220 | 21,734 | 2.584 | 67.688 |
| | 1997 | 120.400 | 4.438 | 1.939 | 4.765 | 2.714 | 7.241 | 1,362 | 3.624 | 3,865 | 77.474 | 2.978 | 10.000 |
| | 1998 | 96.400 | 2.230 | 1,430 | 4.550 | 2.100 | 6.400 | 780 | 2.880 | 1,930 | 62.050 | 2.050 | 10.000 |
| TOTAL SCIENCE, AERONAUTICS AND TECHNOLOGY | 1996 | 5,670,400 | 103,969 | 28.334 | 609.852 | 69.067 | 390.835 | 86.697 | 390,138 | 428.097 | 1,975,293 | 1,037,248 | 550.870 |
| | 1997 | 5,453,100 | 75.138 | 29.439 | 677.321 | 79.914 | 323.501 | 101.449 | 411,477 | 368.220 | 2,162,869 | 970,559 | 253.213 |
| | 1998 | 5,642,000 | 64,030 | 31,430 | 638.015 | 33,000 | 355.049 | 114.074 | 419.320 | 383,901 | 2,291,979 | 1,014,710 | 296.492 |

Space Science

## SCIENCE. AERONAUTICS AND TECHNOLOGY

## FY 1998 ESTIMATES

## BUDGET SUMMARY

**OFFICE OF SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| * Advanced x-ray astrophysics facility (AXAF) | 237.600 | 178.600 | 92.200 | SAT 1-15 |
| * Space Infrared Telescope Facility | -- | -- | 81.400 | SAT 1-19 |
| * Relativity mission | 51.500 | 59.600 | 45.600 | SAT 1-23 |
| * Cassini | 191.500 | 89.600 | 9.000 | SAT 1-26 |
| * Thermosphere. Ionosphere. Mesosphere Energetics and Dynamics (TIMED) | -- | 18.200 | 48.200 | SAT 1-28 |
| Payload and instrument development | 25.900 | 16.900 | 12.300 | SAT 1-30 |
| * Explorers | 132.200 | 125.000 | 142.700 | SAT 1-34 |
| * Discovery | 102.200 | 76.800 | 106.500 | SAT 1-41 |
| * Mars surveyor | 111.900 | 90.000 | 139.700 | SAT 1-46 |
| * New Millennium | 43.500 | 48.600 | 75.700 | SAT 1-50 |
| Advanced space technology | 143.300 | 132.000 | 151.200 | SAT 1-55 |
| Mission operations and data analysis | 563.600 | 583.300 | 507.400 | SAT 1-66 |
| Supporting research and technology | 239.400 | 246.000 | 311.200 | SAT 1-77 |
| Suborbital program | 88.000 | 64.100 | 84.400 | SAT 1-91 |
| Launch services | 245.300 | 240.600 | 236.300 | SAT 1-96 |
| Total | 2.175.900 | 1.969.300 | 2.043.800 | |

* Total Cost information is provided in the Special Issues section

## SCIENCE. AERONAUTICS AND TECHNOLOGY

## FY 1998 ESTIMATES

## BUDGET SUMMARY

| Distribution of Program Amount bv Installation | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Johnson Space Center | 3,600 | 3.600 | 4.100 |
| Kennedy Space Center | 5.100 | 9.000 | 9.800 |
| Marshall Space Flight Center | 356.200 | 307.900 | 202.000 |
| Ames Research Center | 94.400 | 71,000 | 79,400 |
| Langley Research Center | 8.600 | 9.000 | 15.100 |
| Lewis Research Center | 23.200 | 27,400 | 26.400 |
| Goddard Space Flight Center | 764.800 | 842.000 | 901.700 |
| Jet Propulsion Laboratory | 753.900 | 655.300 | 717.300 |
| Headquarters | 166,100 | 44,100 | 88,000 |
| Total | 2,175,900 | 1,969,300 | 2,043,800 |

## OFFICE OF SPACE SCIENCE

### PROGRAM GOALS

The mission of the Office of Space Science (OSS) is to seek answers to fundamental questions about:

The Galaxy and the Universe: What is the universe? How did it come into being? How does it work? What is its ultimate fate?

The Connection between the Sun, Earth, and Heliosphere: How does the Sun influence Earth and the rest of the solar system? What causes solar variability?

The Origin and Evolution of Planetary Systems: What was the origin of the Sun, the Earth, and the planets, and how did they evolve? Are there worlds around other stars? What are the ultimate fates of planetary systems?

The Origin and Distribution of Life in the Universe: How did life on Earth arise? Did life arise elsewhere in the universe?

Many of the primary products of space science are intangible: knowledge and discoveries about the universe in which we live and the laws that govern it. The American public, as an investor in space science research, gains a greater understanding of the universe, inspiration at its wonders and improved education. However, the process of exploration also demands advances in technology -- such as sensors, electronics, robotics, automation, communications, and power generation and control systems -- that provide more tangible benefits to our society. Morover, new space science discoveries offer other tangible returns: for example, it may soon be possible to characterize "spaceweather" and its dependence on the Sun's variability. Violent space "storms." which can profoundly affect space- and Earth-based communication and transportation systems, may soon be predicted by means of Sun and solar wind monitors now under development, coupled with advanced theoretical and empirical models of the coupling of the Sun to the Earth. These intangible and tangible benefits attest to the value of space science to our Nation and the world.

### STRATEGY FOR ACHIEVING GOALS

#### Science

The Space Science program acquires knowledge and makes discoveries by exploring. We explore physically, by means of space probes and planetary landers and orbiters. We explore remotely, by means of telescopes and other observatories, in Earth or heliocentric orbit, observing the Sun, the solar system, and the distant universe.

Space Science is exploring in order to answer questions that are as old as human thought, yet recent discoveries have generated new excitement about the origin and evolution of the Universe, and about the possibility of life elsewhere in, or beyond, our solar system. In October, 1996, three dozen biologists, planetary scientists, astronomers, and cosmologists were assembled in Washington, D.C. by NASA and the National Research Council at the request of the White House Office of Science and Technology Policy. In a workshop format, the group considered emerging directions in space science and identified "Origins" as a unifying theme for future initiatives. The conclusions of the group, some of which are summarized below, were presented to the Vice President at a symposium on December 11, 1996, at the White House. The complete findings of the group are available on the World Wide Web via http://www.hq.nasa.gov/office/oss, under the Space Summit link.

The study of Origins follows a 15-billion-year-longchain of events. The chain begins at the birth of the universe at the Big Bang, moves through the formation of the chemical elements and of the galaxies, stars and planets, continues through the mixing of chemicals and energy that cradled life on Earth, before reaching the earliest self-replicating organisms and then the profusion of life.

For the first time in history, we have achieved the level of understanding and technical capability necessary to fill in "missing links" along the chain of Origins by exploring on the Earth and outward in space, in the present and backward in time. Recent discoveries from diverse disciplines attest that life is remarkably hardy and that each step in the chain of Origins occurred surprisingly quickly. Discoveries in just the past few years provide the first scientific basis for believing that life may be widespread in the universe, in our solar system and beyond. We also have a new comprehension of the development of the universe, its constituent galaxies and stars, the number and variety of planetary systems, and the processes that shape them. To fill in the final links, we need to understand more about the processes leading to the origin of life, about habitats suitable for life, and about the origins of the building blocks of the universe.

Understanding of the final links is within reach. Major advances over the next 15 years can be realized by continuing and building upon the multidisciplinary programs that have brought us to this point. NASA's current and planned Space Science programs begin the next steps in the quest for Origins and pose the technology challenges needed for subsequent steps. Missions now underway and in planning, including Hubble Space Telescope upgrades, the Advanced X-ray Astrophysics Facility, the Space Infrared Telescope Facility, the Stratospheric Observatory for Infrared Astronomy, the Mars Surveyor series, and other planetary and space astronomy and physics projects, will offer powerful tools for advancing the Origins program. At the same time, while the Origins challenge provides a unifying core for the Space Science program, neighboring disciplines address important problems of their own, and may unexpectedly contribute directly -- as was the case for the recent analyses of Martian meteorites. These related activities span the broad panoply of laboratory, field, and theoretical research conducted by NASA. Existing NASA planning processes, coordinated with NSF and other agencies and using peer review, are the best way to define the details and priorities of these programs.

The FY 1998 Budget request includes an increase for several Origins-related programs. These include:

an increase for the Mars Surveyor program to allow for the launch of a Mars sample return mission in the middle of the next

decade, and to increase the scientific robustness of the program:

a new Exploration Technologies Development program, to enable bold, new, low-cost experiments on the surface of solar system bodies:

augmentations to the New Millennium program to enable aggressive development and demonstration of new technologies for the highly demanding new Space Science missions:

full development of the Keck II ground-based interferometer, to enable direct detection of planets around other stars;

an increase in astrochemistry/astrobiology research and analysis, to support the multidisciplinary study of the origin and evolution of pre-biotic material, the origin and distribution of life, the adaptation of life to space, and space studies of life on Earth.

These initiatives are responsive to the President's new Civil Space Policy, which calls for:

A sustained program to support a robotic presence on the surface of Mars by the year 2000 for the purposes of scientific research, exploration and technology development:

A long-term program, using innovative technologies, to obtain in-situ measurements and sample returns from the celestial bodies in the solar system:

A long-term program to identify and characterize planetary bodies in orbit around other stars.

Investment in a balanced and diversified Origins program is expected to yield a steady return of significant findings and, inevitably, major surprises. Over the next 15 years, scientists and the public could share the excitement of discoveries such as:

when and how primitive life emerged and flourished on Earth;

whether the Martian meteorites found on Earth or rocks returned from Mars confirm that life existed on that planet:

the presence of a liquid water Ocean on Jupiter's moon Europa that could harbor primitive forms of life:

the detection of dozens of planetary systems, including some which may be conducive to life as we know it:

sharp pictures of planet-forming disks, infant stars and the growth of galaxies:

more detailed histories of the early stages of the universe, including maps of the dark matter seeds that grew to form galaxies.

The Hubble Space Telescope images of embryonic solar systems and the evidence for possible past life on Mars have aroused intense public interest in the Origins of the universe and its contents. These breakthroughs are the astonishing returns from years of investment in many scientific disciplines. The Origins quest informs, excites and inspires the public. Its outcome could well have as profound an effect on human thought as the Copernican and Darwinian revolutions.

## Education and public outreach

In 1995 the Office of Space Science published an education and public outreach strategy. More recently, OSS and the Space Science Advisory Committee chartered a Task Force of scientists and educators to consider how this strategy should be implemented. The recommendations of the Task Force were published in October 1996, and are available in full on the World Wide Web at http://www.hq.nasa.gov/office/oss/pubs.htm. The Task Force concluded that, in order to have a significant impact on improving the quality of science, mathematics and technology education, and on enhancing public understanding of science in the United States, OSS must take a comprehensive, integrated approach. A series of one-on-one, or few-on-one, interactions between the public and OSS-sponsored scientists cannot have a significant impact. The Task Force recommended the creation of a distributed, decentralized 'Ecosystem" or network for space science education to foster a wide variety of highly-leveraged education/outreach activities. The results of those activities would then be disseminated across the country.

The foundation of this "Ecosystem" is the set of participants in the Space Science program located at universities, federal and non-federal laboratories, and aerospace industries. Superimposed upon this foundation are sets of "nodes" of three different types:

The producers of educational materials and products which draw upon the results of OSS activities. These products are in a form either directly usable or easily adaptable for use in education and public outreach:

The archivers/disseminators of educational products who ensure that such products are known, widely available, and easily accessible:

A set of brokers/facilitators who aggressively search out high-leverage opportunities for education/outreach; arrange alliances between individual scientists or scientific teams and educators to realize those opportunities: and help the space science community turn results from missions and research programs into educationally appropriate products which can be distributed nationally.

In many cases, existing institutions are in a position to take on one or more of these roles, so that limited OSS resources can be directed toward value-added activities rather than toward the creation and maintenance of institutions. In practice, the system envisioned by the Task Force starts with the identification of an educational need; continues with the formation of a partnership between scientists and educators (through the use of a broker/facilitator if necessary) for the specific purpose of meeting that need: and leads to the development of educational materials which are then catalogued and distributed by an archiver/disseminator to a wide variety of users. A set of Implementation Principles governs the operations of the 'Ecosystem" and also serves as a basis for making decisions concerning the types of education/outreach activities which OSS should sponsor

and/or support. The Task Force identified a subset of its more than 50 individual Findings and Recommendations which require near-term actions in order to proceed with the development of the "Ecosystem". OSS intends to pursue the recommendations of the Task Force.

### Technology development and transfer

The Office of Space Science Integrated Technology Strategy establishes the framework through which OSS will team with partners in NASA and industry to develop the critical technologies required to enhance space exploration, expand our knowledge of the universe, and ensure continued national scientific, technical and economic leadership.

The OSS vision of success for its Integrated Technology Strategy is the embodiment, at all levels and across all disciplines, of a continued commitment to develop, utilize and transfer technologies that provide scientific and globally competitive economic returns to the nation. To attain this vision, OSS strives to meet four primary goals: (1) OSS will identify and support the development of promising new technologies which will enable or enhance space science objectives and reduce mission life-cycle costs: (2) OSS will infuse these technologies into space science programs in a manner that is cost effective, with acceptable risk: (3) OSS will establish technology transfer as an inherent element of the space science project life cycle: and (4) OSS will support the development of strong and lasting implementing partnerships among industry, academia and government to assure the nation reaps maximum scientific and economic benefit from its Space Science program.

With its Integrated Technology Strategy, the Office of Space Science will contribute to both NASA crosscutting and Space Science mission-specific spacecraft technology advancements. This new role of ensuring crosscutting technology infusion will serve both internal and external customers. NASA's internal customers consist of the Human Exploration, Space Science, Mission to Planet Earth, and Aeronautics Enterprises. External customers include both the aerospace and non-aerospace industry, as well as other government agencies. Investments in spacecraft, science instrument, and ground or space-based systems technologies will ensure that new technologies continue to become available to enable innovative and cost-effective future missions. The crosscutting technology advancements will be achieved through a balance of near-term and far-term activities. Near-term (< 5-year) development will be targeted to specific user needs for currently planned missions, and far-term basic research (>5-year horizon) will identify and exploit major new scientific and technical discoveries to enable new missions.

## MEASURES OF PERFORMANCE

The Office of Space Science has been working with the Office of Management and Budget, the NASA Advisory Committee, and NASA's Office of Policy and Plans to develop metrics in response to the Government Performance and Results Act (GPRA) of 1993. Although the following metrics are not the final set which will be used to address GPRA, they are indicative of the issues under consideration.

## Fundamental Science

Fundamental Science is the primary objective of the Space Science program, however, it is also among the most difficult of outcomes to measure. OSS has developed two surrogate measures of fundamental scientific performance, each of which are based on assessments that are made independent of NASA. These metrics do not capture all aspects of performance that need to be measured, but they do provide important insights into fundamental scientific performance.

1) "Science News" metric - This metric is based on that journal's annual listing of "most important stories" going back 24 years (1973 - 1996). "Science News" tracks the new discoveries they consider most significant on an annual basis. By tallying the stories based on scientific or technical accomplishments each year, a metric is generated that can be used to compare OSS performance over time as compared to all other "world class" science in fields as diverse as archaeology and biomedicine. The following is a synopsis of our observations as of the end of 1996:

Space Science discoveries have contributed 4.1% of world science return over the past 24-year period.

Missions with the largest return by this metric from 1973-1996 are Hubble Space Telescope (HST), Viking and Voyager.

Significant contributions are also derived from Pioneer, the Compton Gamma Ray Observatory, Solar Maximum Mission and the Infrared Astronomy Satellite.

A sharp spike in the mid-70s reflects the Viking mission to Mars in 1976. A second spike is seen in the late 1970s, led by Voyager's encounter with Jupiter. In contrast, the 1980's shows a steep decline, commensurate with the loss of Challenger which delayed the launch of new missions for several years.

The late 1980s and early 1990s has seen a dramatic increase in science output, driven largely by the start of prime mission operations of major missions such as HST, the Cosmic Background Explorer (COBE) and Magellan.

1994 was the best year on record for OSS, as Space Science discoveries contributed 9% of world science return, led by HST discoveries which produced over 5% of world scientific output. HST's output is the best performance for a single OSS program since Viking landed on Mars in the mid-70s. 1995 showed a slight decline, but was still well over the historical average. 1996 was another outstanding year, with Space Science accounting for 7% of world-wide discoveries. This output was led by the discovery of possible fossils of primitive life in a meteorite from Mars. HST also continues to make headlines, producing 3.5% of world discoveries in 1996 by itself, while the arrival of Galileo at Jupiter has led to the start of what is expected to be a succession of ground-breaking discoveries.

2) College Textbook metric - This metric attempts to show how the most significant topics of a single year get incorporated into the overall body of scientific knowledge. Six editions of a popular introductory college astronomy textbook spanning 1979-1995 were analyzed to assess OSS contributions. Long-term performance is measured by OSS's capture of "intellectual market share" (i.e. what percentage of the material is based on OSS contributions) as well as by overall growth of knowledge about astronomy.

Textbook material based on Space Science contributions grows steadily, reflecting the cumulative effect of new information which is added to the overall body of scientific knowledge as new discoveries are added.

The textbook grew 33% from 1979 to 1995, with the largest contributor being new chapters on Saturn, Uranus and Neptune, resulting from NASA deep space missions to the outer planets.

In 1995, 27% of knowledge presented in the textbook was based on OSS contributions, which is double the 13% OSS contribution in 1979.

Additional credibility accrues to these two metrics because of the significant correlation between the identification of new discoveries in "Science News" followed by their inclusion into college text 3-5 years later. An enclosed chart identifies the historical performance of OSS over the past 24 years in accordance with the two metrics just described.

**Faster, Better, Cheaper**

A major strategic thrust of OSS is to increase overall cost effectiveness of the Space Science Enterprise by providing more frequent access to space for the science community within an increasingly constrained budget environment. Current plans within the Space Science program call for a significant increase in the historical launch rate despite reduced resources. Toward this end, OSS has restructured several missions to reduce cost and schedule requirements. Mission series such as Explorers, Discovery, Mars Surveyor and New Millennium all emphasize the selection of future missions within predetermined cost, schedule and launch services requirements. The success of this new strategy is measured by three important criteria:

1) Development time - Mission development time is a key factor in putting fresh ideas into practice and in the overall cost of a mission, and, therefore, must be reduced from historical levels. OSS plans to reduce development times from an average of more than 9 years for missions launched in 1990-94 to less than four years for missions planned for launch in 2000-04.

Future Explorers (i.e. MIDEX, UNEX and SMEX) are planned for 2-3 year development times vs 4-5 year development times of previous Delta-class missions.

Discovery missions are planned for 3 year development schedules (or less)

Mars Surveyor missions are planned for 3-4 year development schedules

New Millennium missions are planned for 2-3 year development schedules

2) Development cost - Given the tightly constrained NASA budget plans for the next several years, mission development costs must be reduced, and cost estimate overruns must be eliminated if OSS is to sustain a reasonable launch rate for new missions. Consequently, NASA is now planning the majority of future missions to fit within a predetermined cost "cap" or target.

Future Explorer missions are targeted at specific costs in FY 1994 dollars, all well below historical cost levels: Medium Explorers (MIDEX)($70M); Small Explorers (SMEX) ($30-40M); University Explorers (UNEX)($5M).

The FUSE mission has been restructured from a $254 million Delta-class mission to a $100 million Med-Lite class mission, while the launch date has been accelerated by approximately two years.

SIRTF, an FY 1998 new start, has been extensively restructured from its original configuration in order to reduce its development costs by a factor of 4 over the original estimate.

Discovery missions are constrained to no more than $150 million FY 1992 dollars for development, a fraction of what planetary missions have historically cost. The first four Discovery missions (Mars Pathfinder, **NEAR,** Lunar Prospector, and Stardust) are actually averaging less than $110 million FY 1992 dollars for development.

Mars Surveyor and New Millennium missions, while not strictly capped during the definition phase, are capped at the time of selection for development.

Additional savings are achieved by constraining future mission designs to smaller, less expensive launch vehicles (i.e. Med-Lite, Small-class, Ultra-Lite) as opposed to Delta-class or higher as historically has been the case.

3) Launch rate - The provision of more frequent launch opportunities is essential to foster the next generation of space scientists and engineers, and to provide a more continuous flow of exciting new discoveries.

MIDEX, SMEX and UNEX mission launches are anticipated at the rate of nearly 1 launch per year for each mission class, contingent upon available funding and the specific missions selected. We expect to significantly increase the UNEX launch rate around the beginning of the next decade, assuming availability of low-cost launchers

Discovery and New Millennium missions each support an annual launch rate of 1 launch every 12-18 months

The Mars Surveyor program supports 2 launches at every Mars launch opportunity (i.e. every 2 years)

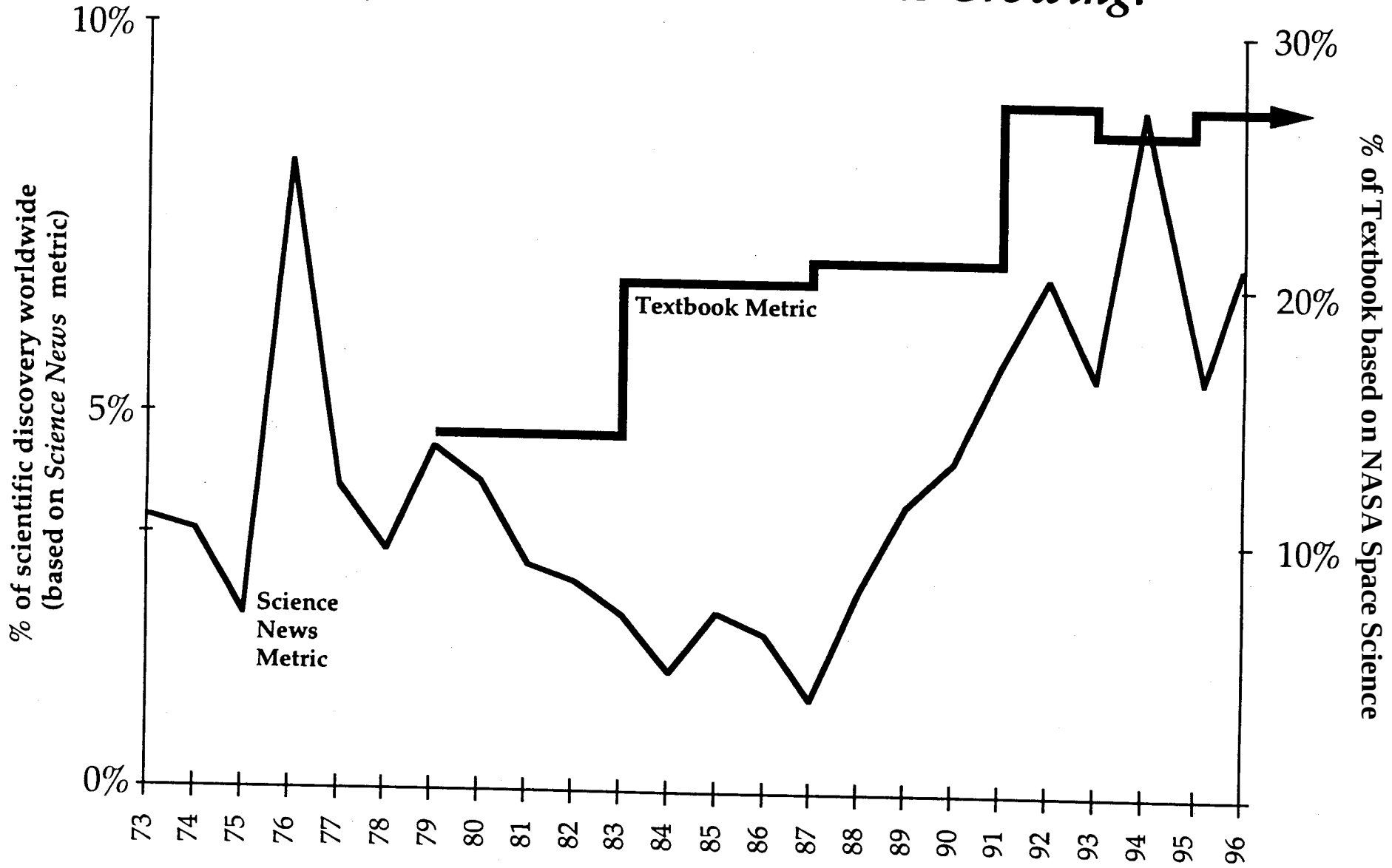
A graph following **this** section illustrates the projected trend in declining mission cost and schedule requirements while accelerating the annual launch rate beyond FY 2000.

In addition to reductions in cost and schedule requirements for development and launch of spacecraft, OSS has sought cost effectiveness in mission operations and data analysis (MO&DA). This is the phase where the principal science objectives of every endeavor are accomplished. MO&DA is definitely becoming "better" and "cheaper", as illustrated by the average cost per year of operating missions. In 1994 the Office of Space Science operated 14 missions at an average cost of $20M per year per mission. Our current plans for FY 2002 include operation of 29 missions at an average cost of $6.3M per year per mission, a factor-of-3

improvement. (These figures exclude HST, AXAF and Cassini, large missions which would skew the data). MO&DA costs have been reduced by using smaller, "smarter" spacecraft, accepting more risk in mission operations, reducing funding to scientists after completion of the primary mission phase, and arranging for more international collaborations. A graph following this section illustrates the effects of these changes.

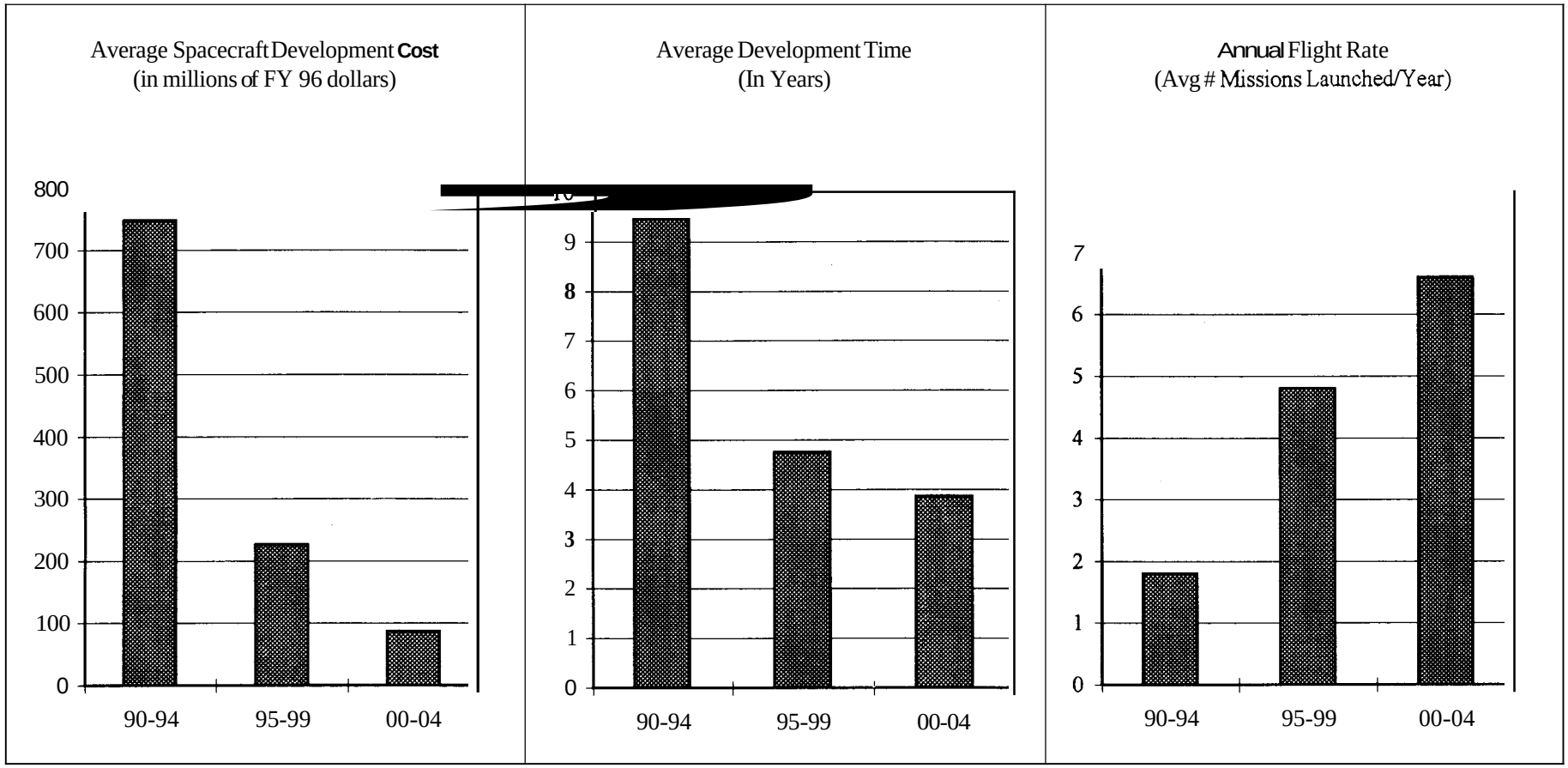
# Fundamental Science Metrics

## *NASA Space Science Contributions Growing!*

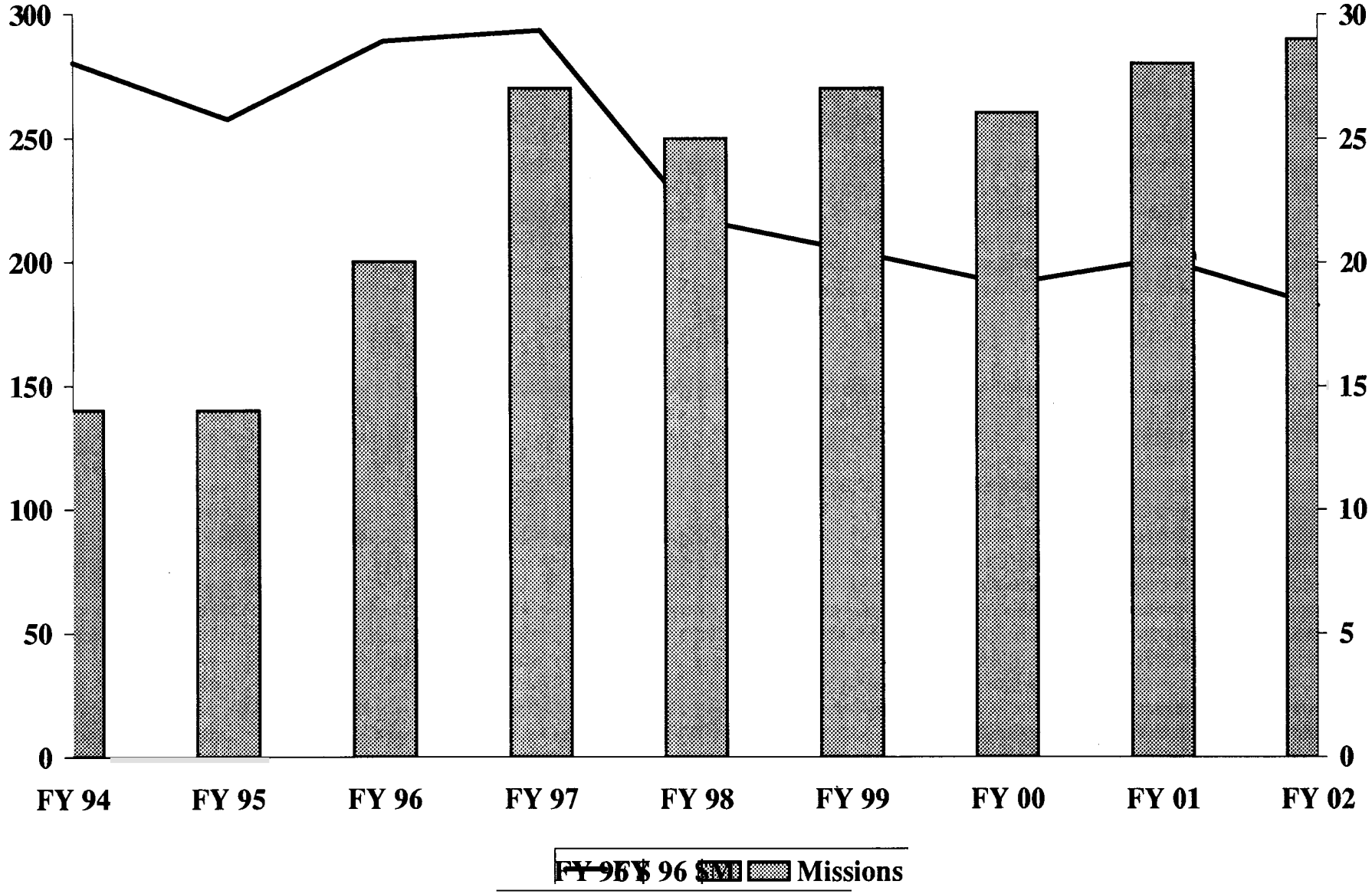


# The Space Science Enterprise

## Faster, Better, Cheaper



# Space Science MO&DA (less HST, AXAF, Cassini)
## Efficiencies Achieved!



## BASIS OF FY 1998 FUNDING REQUIREMENT

### ADVANCED X-RAY ASTROPHYSICS FACILITY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Advanced x-ray astrophysics facility development * ..... | 237,600 | 178,600 | 92,200 |

* Total cost information is provided in the Special Issues section

### PROGRAM GOALS

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. AXAF will observe matter at the extremes of temperature, density and energy content. Previous x-ray missions, such as the Small Astronomical Satellite-C and the Einstein Observatory have demonstrated that observations in the x-ray band provide a powerful probe into the physical conditions of a wide range of astrophysical systems. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, AXAF will provide unique and crucial information on the nature of objects ranging from nearby stars like our Sun to quasars at the edge of the observable universe. Some of the major scientific questions addressed by AXAF include:

What is the age and size of the universe? AXAF will provide an independent measurement at x-ray wavelengths of the Hubble constant, which determines the answers to these questions. Brighter binary sources in galaxies within the Virgo cluster can be resolved and detected individually, as can sources in intermediate galaxies. Thus, the population of bright X-ray sources in hundreds of galaxies can be determined. Since high-energy X-rays are unaffected by obscuring material, the brightness of sources can be accurately measured and the hypothesis that these sources, or a subset of them, are "standard candles" can be accurately tested. If such "standard candles" are found, distances to nearby galaxies can be accurately determined. These distances are a crucial step in the derivation of the Hubble Constant and the potential of these measurements is truly exciting.

What is dark matter? Dark matter accounts for more than 90% of the mass of the universe, but what it is remains a total mystery. The gravitational effects of dark matter have proven its existence, but it has yet to be identified. It may be massive amounts of ordinary matter in the form of small, non-radiating objects yet to be detected, or it may be some exotic new form of matter. AXAF will be able to map the distribution of dark matter in distant clusters of galaxies, contributing to our understanding of this enigma.

What is the x-rav backmound radiation? Other x-ray missions have seen a faint x-ray background emission covering the entire sky, the nature of which is uncertain. AXAF is expected to detect quasars and active galaxies 100 times fainter than the Einstein Observatory could, and can thus look to significantly greater distances. This is unknown territory, except that

the integrated emission from many unresolved faint sources probably contributes most of the X-ray background. Deep *AXAF* observations will come close to imaging this background and will provide a sample of distant objects which record the state of the universe at early times.

## STRATEGY FOR ACHIEVING GOALS

The Marshall Space Flight Center (MSFC) was assigned responsibility for managing the *AXAF* Project 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. TRW was selected as prime spacecraft contractor for the mission, with major subcontracts to Hughes Danbury (mirror development), Eastman Kodak (High Resolution Mirror Assembly -- HRMA), and Ball Aerospace (Science Instrument Module - SIM). The Smithsonian Astrophysical Observatory (SAO) also has significant involvement throughout the program. AXAF will be launched on the Shuttle with an Inertial Upper Stage (IUS) provided by Boeing. International contributions are being made by the Netherlands (an instrument), Germany (an instrument), Italy (detector test facilities), and the United Kingdom (microchannel plates and science support).

*AXAF* was given new start approval in FY 1989, with full-scale development contingent upon demonstrating the challenging advances in mirror metrology and polishing technology. The first pair of mirrors were fabricated and tested in a specially designed X-ray Calibration Facility (XRCF) at MSFC in 1991, and the x-ray results validated the metrology and polishing. With the success of this Verification Engineering Test Article (VETA) # 1 demonstration, the program proceeded fully into design and development.

The AXAF program was restructured in 1992 in response to downward revisions of the 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 life time, 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 payload on the Japanese Astro-E mission to mitigate the science impact of losing AXAF-S. This activity is underway, and funding for Astro-E activities is requested within the Payload and Instrument Development line.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| AXAF Observatory CDR<br>Plan: February 1996<br>Actual: February 1996 | This major milestone was achieved on schedule. The review assessed the validity and maturity of observatory design as a functionally integrated system in terms of subsystem compatibility, interface requirements and ability to meet all established performance criteria within acceptable levels of technical, cost and schedule risk. |

| | |
|---|---|
| Science Instrument Module (SIM) completed<br>Plan: April 1996<br>Revised: June 1997 | Fabrication of the Science Instrument Module completed at Ball Aerospace. The SIM will house the two focal plane science instruments on AXAF. Completion of this milestone is now scheduled for June 1997; a SIM surrogate was delivered to the XRCF in September 1996 to support calibration, with no impact to critical path slack. |
| Deliver flight instruments<br>Plan: August 1996<br>Revised:<br>January 1997 (HRC) &<br>March 1997 (ACIS) | Flight instruments shipped upon completion of integration and test activities. An ACIS surrogate was delivered to the XRCF in September 1996 to support calibration, with no impact to critical path slack. |
| X-ray calibration begins at MSFC<br>Plan: January 1997 | Tests will verify HRMA mirror alignment and compare technical performance of mirrors and science instruments against predicted values. On schedule. |
| Complete HRMA/Instrument calibration<br>Plan: April 1997 | Verification of end-to-end optical performance. On schedule. |
| Begin Observatory assembly and test<br>Plan: October 1997 | Initiate integration of completed spacecraft with telescope and instruments at TRW, followed by full-up systems testing (thermal-vacuum, acoustic, etc.). On schedule. |
| Deliver Observatory to KSC<br>Plan: June 1998 | Observatory integration and systems testing completed at TRW. Begin integration with upper stage, final performance testing, and integration in Shuttle. On schedule. |
| Launch Observatory<br>Plan: August 1998 | Shuttle deployment into low-Earth orbit followed by upper stage delivery to highly elliptical operational orbit. On schedule. |

## ACCOMPLISHMENTS AND PLANS

Detailed design activities for the spacecraft were completed on time in December 1995, and fabrication of the flight structure began in early 1996. The spacecraft Structural Test Article was completed in January 1996, and static testing was completed in April. The CDR for the entire *AXAF* Observatory was completed in February 1996.

A major milestone was achieved in November, with the completion of the integrated High Resolution Mirror Assembly (HRMA). After all mirrors were bonded into the HRMA, testing showed that it will meet all specifications for the accurate focusing of x-rays. The HRMA has been delivered to MSFC to support the start of calibration testing in January 1997.

As mentioned above, technical problems with the science instruments and the Science Instrument Module (SIM) have resulted in delays in the deliveries of flight models. A surrogate ACIS instrument and a surrogate SIM have been delivered to support XRCF testing: flight models will be delivered and integrated later. This adjustment to the schedule will allow the HRMA to be completely tested in the XRCF, without serious loss of critical path slack.

Following completion of XRCF testing in April, the HRMA will return to TRW for final integration with the flight instruments, the flight SIM, the transmission gratings, and other elements of the telescope assembly. Meanwhile, assembly and test of the spacecraft structure and support systems will continue through the end of the fiscal year. The telescope assembly and the spacecraft are scheduled for completion before the end of fiscal 1997, leading to the start of Observatory integration and testing in October. Observatory integration and testing will continue through June 1998, when the completed AXAF will be delivered to KSC for launch integration and then launch on the Shuttle in August.

Program costs are at or below planned levels, and reserves (as a percentage of work to go) are holding steady.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE INFRARED TELESCOPE CILITY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| SIRTF development * ..... | -- | -- | 81,400 |

* 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. SIRTF is the fourth of NASA's Great Observatories, which include the Hubble Space Telescope, the Compton Gamma Ray Telescope, and the Advanced X-Ray Astrophysics Facility. By completing NASA's family of Great Observatories, an infrared capability will enable the full power of modem instrumentation to be brought to bear, across the entire electromagnetic spectrum, on the central questions of modem astrophysics. Many of these questions can be unraveled only by the full physical picture that this broad spectral coverage uniquely provides.

Rather than simply "descoping" the original Titan-class SIRTF -- the original "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. 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 modem astrophysics for which SIRTF could make unique and important contributions. These primary science themes, which have recently 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 (whichjudged SIRTF the highest priority major new program for all of U.S. astronomy in the 1990s). The focus of SIRTF's impressive scientific capabilities will be on:

Protoplanetary and Planetary Debris Disks. One of the most exciting and unexpected discoveries of the Infrared Astronomical Satellite (IRAS) survey was that many nearby stars are surrounded by disks of material like the dust in our own Solar System. Modeling of the IRAS data suggests that these disks contain particles ranging in size from ~ 1 mm up to bodies as large as

asteroids and comets, with some arguments suggestive of still larger, planet-sized objects. Further exploration of this phenomenon will help us understand the frequency and properties of planetary systems around nearby stars. SIRTF is expected to contribute significantly to this exploration by imaging the nearby examples in great detail, searching for possible empty inner regions caused by planets. SIRTF's ability to study debris disks around literally thousands of stars should allow the relations between planetary debris disk properties and stellar mass, luminosity, age, and multiplicity to be determined, revealing fundamentals of planetary system formation.

Brown Dwarfs and Super Planets. Brown dwarfs are objects with masses between 0.001 and 0.08 that of the Sun (0.001 - 0.08 M[sun]). They are too low in mass to sustain nuclear burning but may be visible in the infrared as they radiate the gravitational energy released in their formation. They are of particular interest because they may account for some of the "missing mass" which forms a dynamically significant, but as yet unseen, halo for our Galaxy -- and other galaxies as well. As brown dwarfs age, they become cooler and fainter in the infrared. However, in a single 600-second integration at the 4.5-micron wavelength, SIRTF is designed to detect 0.03 M[sun] objects with ages of 10 billion years -- as is appropriate for the halo of our Galaxy - at distances up to about 100 light-years from the sun. If the missing mass in our galaxy is in the form of 0.03 solar mass brown dwarfs, approximately 1000 of them should be present in the data base created by a SIRTF survey which will cover about 1% of the sky.

Ultraluminous Galaxies and Active Galactic Nuclei. IRAS identified several new classes of infrared-luminous galaxies. One such class which was found in the main IRAS catalogs is the ultraluminous galaxies (ULGs),which have optical images suggestive of violent interactions and mergers, and luminosities well into the luminosity range of quasars. More recently, several even more luminous galaxies have been found through followup studies of the IRAS Faint Source Catalog and Database. These Active Galactic Nuclei (AGNs) radiate 90 to >99% of their total luminosity at infrared wavelengths. SIRTF is designed to detect ULGs billions of light-years away and study their evolution in space-time. If ULGs are triggered by galaxy interactions, there should be more of them at earlier epochs, when the higher density of the universe would have led to more frequent galaxy-to-galaxy interactions. The same observations would detect AGN objects near the edge of the observable universe and determine whether they are different -- perhaps powered by a different physical mechanism -- than the lower luminosity ULGs. SIRTF should be able to determine the physical conditions in the interiors of these objects, thereby determining the source of their luminosity.

The Early Universe -- Deep Surveys. SIRTF's deep imaging at wavelengths between 3 and 8 microns is designed to probe the early universe. These measurements will permit a determination of redshift, the speed at which distant objects are receding from us. Comparison of SIRTF's census of galaxy quantities and properties as a function of redshift will test our understanding both of the evolution of galaxies and of the geometry of space-time. The investigations of the most luminous infrared galaxies discussed earlier will provide additional insights into the early universe. It has been suggested that these objects may be protogalaxies -- undergoing an initial cataclysmic burst of star formation -- because their luminosity is far too high to be sustained by nuclear burning in a normal stellar population. If this conjecture is true, the numbers of such objects ought to increase markedly with look-back time, and SIRTF's ability to detect them ought to reveal many new examples.

While these topics drive the mission design, SIRTF's powerful capabilities have the potential to address a wide range of other astronomical investigations, including studies of the outer solar system, the early stages of star formation, and the origin of chemical elements. Taken together, SIRTF's design capabilities are expected to allow it to achieve many of the initial goals of the Origins program, which are outlined in the Space Science summary section. Moreover, 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 FY 1998 budget proposes appropriation language for multi-year funding of SIRTF development and launch costs. The requested appropriations are $81.4 million for FY 1998. $134.5 million for FY 1999, $130.0 million for FY 2000, $1 17.3 million for FY 2001 and $25.8 million for FY 2002, for a total of $489.0 million. Enactment of these appropriations will ensure the stability to manage and execute this program within its budget and schedule commitments.

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 will be 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) will be developed by Ball Aerospace and Technologies Corporation, Boulder, CO, as an industrial member of the SIRTF Integrated Project Team, and will consist of all of the elements of SIRTF that will operate in space at reduced or cryogenic temperatures. This will include the telescope, telescope cover, cryostat, and supporting structures and baffles. The cryostat will contain the cold portions of the PI-supplied Science Instruments.

The Spacecraft Assembly will be developed by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an Industrial member of the SIRTF Integrated Project Team, and will consist 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 K, and will 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 will be 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 SIs, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF will be performed by this element.

Ground and Operations System development will be accomplished in parallel with Observatory development. This will be done to reduce redundant development of ground equipment and to assure compatibility between ground equipment and the Observatory after launch. This equipment will be developed by the mission development team at JPL.

SIRTF is planned for launch on a Delta launch vehicle during FY 2002.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Non Advocate Review (NAR)<br>Plan: October 1997 | The review will demonstrate that SIRTF has a plan for the design and development that is credible and consistent with NASA resources and science community expectations. |
| Preliminary Design Review<br>Plan: October 1997 | Review at the completion of the functional design of SIRTF to demonstrate that the project is technically ready to proceed with detail design (Phase C). |
| Start Phase C/D<br>Plan: April 1998 | Approval by NASA to proceed with the design and development of the SIRTF project. |
| Critical Design Review<br>Plan: October 1998 | The review at the completion of the detail design will demonstrate that the SIRTF design is credible within planned resources, and that it satisfies the science community's expectations. |
| Launch<br>Plan: December 2001 | Launch on a Delta launch vehicle to a solar orbit trailing the Earth. |

## ACCOMPLISHMENTS AND PLANS

Please refer to the Supporting Research and Technology section for a discussion of FY 1996 - 1997 accomplishments during SIRTF Phase A and Phase B studies. With the funds requested for FY 1998, SIRTF will be able to enter Phase C/D. A Preliminary Design review is planned for October 1997 and a Critical Design Review is planned for October 1998.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### RELATMTY MISSION

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Relativity mission development * ..... | 51,500 | 59,600 | 45,600 |

* Total cost information is provided in the Special Issues section

### PROGRAM GO——

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 in a limited number of ways. 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 a complex process 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 0.2 milliarcsecond per year (the width of a human hair observed from 50 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.) is conducted at Stanford in collaboration with Lockheed/Palo Alto Research Laboratory (LPARL). Spacecraft development and systems integration will be performed by Lockheed Missiles and Space Corporation (LMSC). Launch is scheduled for October 2000 aboard a Delta II launch vehicle.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Flight Model Dewar Delivery<br>Plan: November 1996<br>Actual: October 1996 | Delivery of the largest Helium Dewar ever made for a science mission. Ready for integration with the Probe B prototype for the second series of performance tests. Completed ahead of schedule. |
| Ground Tests-2A start<br>Plan: June 1997 | Conduct the third series of performance tests using the flight model dewar and Probe B prototype. Expected to be accomplished early. |
| Flight Probe Delivery<br>Plan: September 1997 | Supports start of Science Mission payload (dewar, probe, and telescope) integration and testing in early FY 1998. Expected to be completed early. |
| Flight Probe integrated with Science Instrument Assembly<br>Plan: April 1998 | Successful interface of the dewar to the science payload. Expected to be completed early. |
| Launch<br>Plan: October 2000 | Launch aboard a Delta II launch vehicle. Program ahead of schedule to achieve this launch date. |

## ACCOMPLISHMENTS AND PLANS

The program continues ahead of the baseline schedule to launch the Relativity Mission by October 2000. The flight dewar was completed ahead of schedule and advances have been made in the scientific payload design. The second series of ground tests (GTU-1A) demonstrated the proper functioning of many aspects of the design. The third series of ground tests (GTU-2A), which are scheduled to start in June 1997, will incorporate the flight dewar and will transition later (following the delivery of the flight probe, which interfaces the science payload to the dewar) into the final series of ground tests.

The spacecraft development has also made outstanding progress. The PDR was held seven months ahead of schedule, and the spacecraft's unique thrusters and its balancing mechanisms have passed several qualification tests. The spacecraft CDR (planned for October 1997) is also likely to be accomplished significantly ahead of schedule.

An External Independent Readiness Review (EIRR) team is currently being formed to ensure that the mission will meet all established Level 1 technical and scientific requirements.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### CASSINI DEVELOPMENT

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Cassini Development • ..... | 191,500 | 89,600 | 9,000 |

• Total cost information is provided in the Special Issues section

### PROGRAM GOALS

Building on the discoveries made by the Pioneer and Voyager missions, the Cassini program will provide unprecedented information on the origin and evolution of our solar system. It will help tell how the necessary building blocks for the chemical evolution of life are formed elsewhere in the universe. The Cassini mission 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 flyby to expand our knowledge of the Jovian System. In conjunction with Galileo's study of the Jovian system, the mission should also provide much insight as to how and why the large, gaseous outer planets have evolved much differently than the inner solar system bodies.

### STRATEGY FOR ACHIEVING GOALS

Cassini is scheduled for launch in October 1997 aboard a Titan IV launch vehicle. An extensive cruise period is required to reach Saturn, during which the spacecraft will fly by Venus, Earth, and Jupiter to gain sufficient velocity to reach its destination. Upon arrival in June 2004, the spacecraft will begin four years of study of the Saturnian system that will provide intensive, long-term observations of Saturn's atmosphere, rings, magnetic field, and moons. In conjunction with the observations conducted by the spacecraft, the European Space Agency (ESA) - provided Huygens Probe will be injected into the atmosphere of Saturn's moon Titan. The probe will conduct in-situ physical and chemical analyses of Titan's methane-rich, nitrogen atmosphere, that is a possible model for the pre-biotic stage of the Earth's atmosphere. The Cassini spacecraft will also obtain a radar map of most of Titan's surface.

The Jet Propulsion Laboratory (JPL)has been assigned responsibility for managing the Cassini Project and for developing the spacecraft, NASA also has four partners in the Cassini project: the Department of Defense/Air Force is constructing a Titan IV Centaur launch vehicle; the Department of Energy is contributing the Radioisotope Heater Units (RHUs) and Radioisotope Thermoelectric Generators (RTGs) for the mission; the European Space Agency (ESA) is providing the Huygens probe: the Italian Space Agency (ASI) is contributing the High Gain/Low Gain Antenna for the spacecraft and elements of the radar mapper.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Start System Level Tests<br>Plan: May 1996<br>Actual: May 1996 | Integration, test and checkout of fight hardware and instruments. |
| Deliver Flight Model Science Instruments<br>Plan: July 1996<br>Actual: July 1996 | Delivery of flight model instruments to JPL for integration with the spacecraft. |
| Start Spacecraft Environmental Tests<br>Plan: October 1996<br>Actual: October 1996 | Tests entire spacecraft performance in a simulated mission environment to assure proper operation in space. |
| Ship spacecraft to KSC<br>Plan: April 1997 | Complete system level integration and test activities. Begin integration with Titan IV/Centaur launch vehicle at Kennedy Space Center (KSC). On schedule. |
| Spacecraft launch<br>Plan: October 1997 | Development phase complete. Initiate spacecraft checkout and cruise operations. On schedule. |

## ACCOMPLISHMENTS AND PLANS

Cassini spacecraft flight system integration continued through the first half of FY 1996. Engineering model instruments were delivered in mid-FY 1996 for integration and test with the spacecraft systems. Flight model instruments were delivered in late calendar FY 1996 for integration with the spacecraft in preparation for spacecraft environmental tests. ESA also delivered the Engineering Model Huygens Probe in early FY 1996 for integration and test with the spacecraft, and Italy delivered the protoflight High Gain Antenna.

For FY 1997 Cassini funding will support completion of the flight model science instruments, and remaining integration, environmental, and system test activities that are required prior to shipment of the spacecraft to KSC. The spacecraft will be delivered to KSC in April 1997. The RTG's will also be completed and shipped to KSC by the Department of Energy in April, and will be integrated to the spacecraft in July. Ground System software development and testing will be completed in July, and training of the fight operations team will be completed. The Launch Readiness Review and the President's launch decision will be completed in September for an October 1997 launch.

Cassini will be launched in October 1997 aboard a Titan IV/Centaur launch vehicle, and is targeted for its first flyby of Venus in April 1998 for a gravitational assist as it begins its seven-year cruise to Saturn.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| TIMED Development * ..... | -- | 18,200 | 48,200 |

* 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 the Solar Terrestrial Probes (STP) Program, as detailed in Space Science Strategic Plan. TIMED is part of NASA's initiative aimed at providing cost-efficient scientific investigation and more frequent access to space. The TIMED mission is scheduled aggressively, but realistically, for a three year development program, cost-capped at $100 million in FY 1994 dollars. TIMED will be developed for NASA by the John 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 is scheduled for launch in January 2000 aboard a Med-Lite Class launch vehicle. TIMED will begin 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

will carry four instruments: Solar Extreme ultraviolet Experiment (SEE), Infrared Sounder (SABER), Ultraviolet Imager (GUVI), and Doppler Interferometer (TIDI).

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Complete Phase B: start C/D<br>Plan: April 1997 | Complete definition study and initiate the 36-month development effort. On schedule. |
| Non-Advocate Review<br>Plan: February 1997 | Conduct Design Concurrence and Cost Review. |
| Preliminary Design Review<br>Plan: February 1997 | Confirm that the science goals and objectives are achievable within Mission Design. |
| Critical Design Review<br>Plan: January 1998 | Confirmation that the design is sufficient to move into full-scale development. |
| Completion of Instrument Development<br>Plan: December 1998 | Complete delivery of all 4 flight instruments to APL. |
| Begin Spacecraft I&T<br>Plan: January 1999 | Spacecraft integration and test in preparation for launch. |
| Launch<br>Plan: January 2000 | Launch aboard a Med-Lite Launch vehicle |

## ACCOMPLISHMENTS AND PLANS

The TIMED mission was initiated in 1994, and completed requirements definition and conceptual design in 1994. Risk reduction efforts were completed in 1995 to ensure that the mission objectives and science goals are achievable within budget. A definition study (Phase B) for the TIMED mission continued throughout FY 1996, and is scheduled for completion in mid-FY 1997.

A contract for the TIMED development will be awarded in the third quarter of FY 1997 to enable full-scale development of the four instruments and the spacecraft. A Preliminary Design Review (PDR) will be held in first quarter of 1997, with a Critical Design Review (CDR) in the first quarter of 1998. Long-lead procurements will be initiated in FY 1997 to allow APL to meet its target launch readiness date, January 2000. Instrument and spacecraft subsystem fabrication will take place in FY 1998, and instrument and subsystem integration and test will begin in early FY 1999. TIMED will be launched aboard a Med-Lite class launch vehicle.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### PAYLOAD AND INSTRUMENT DEVELOPMENT

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Tethered satellite system | 4,200 | -- | -- |
| Astro-E | 7,400 | 5,600 | 7.100 |
| Mars instruments | 2,600 | -- | -- |
| Shuttle/international payloads | 11.700 | 11.300 | 5.200 |
| Total | 25,900 | 16,900 | 12,300 |

## PROGRAM WACS

Payload and Instrument Development supports a number of instruments and payloads to be used on international satellites or on Spacelab missions. International collaborative programs offer opportunities to leverage U.S. investments, obtaining scientific data at a relatively low cost. Spacelab missions utilize the unique capabilities of the Shuttle to perform scientific experiments that do not require the extended operations provided by free-flying spacecraft. The Payload and Instrument Development program supports investigations in Sun-Earth connections, the structure and evolution of the universe, and exploration of the solar system.

## STRATEGY FOR ACHIEVING GOALS

The Tethered Satellite System (TSS) program is an international cooperative project with the Italian government. The TSS was flown aboard the shuttle in July-August 1992, and reflown in February 1996, to perform space plasma experiments while also investigating the dynamic forces acting upon a tethered satellite.

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 will contribute 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. It will provide high quantum efficiency over a large instantaneous bandpass, from 0.3 to 10 keV, at an unprecedented spectral resolution of approximately 15 eV over the entire bandpass. The foil mirrors will have a large collecting area, approximately 400 square centimeters at 6 keV, and will provide approximately 2 arc second resolution. These capabilities will permit an unprecedented sensitivity study of a wide range of astrophysical sources, answer many outstanding questions in astrophysics, and likely pose many new ones.

The Jet Propulsion Laboratory (JPL) provided two Mars Oxidation (MOx) experiments for Russia's Mars '96mission, which launched unsuccessfully in November 1996.

The Payload and Instrument Development program also supports several other international and U.S. development projects. These include the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer (ORFEUS)and Interstellar Medium Absorption Profile Spectrograph (IMAPS), to be flown on the German-U. S. Shuttle Pallet Satellite (SPAS):the Satelite de Aplicaciones Cientificas-B (SAC-B),the first Argentinean spacecraft: the High Energy Transient Experiment (HETE, 1996). a small satellite for study of gamma-ray burst phenomena in multiple wavelengths: ground-based support for Japan's Very Long Baseline Interferometry Space Observatory Program (VSOP, 1997) and Russia's RADIOASTRON (1999) program: portions of two instruments to be flown on Europe's X-ray Mirror Mission (XMM, 1999); and participation in Europe's International Gamma Ray Astrophysics Laboratory (INTEGRAL, 2001).

ORFEUS/IMAPS, which flew aboard the Shuttle in the summer of 1993 and was reflown in November 1996, has explored the character of extreme and far ultraviolet sources, studied the composition and distribution of matter in the neighborhood of the Sun, and performed direct observations of the interstellar medium.

SAC-B and HETE were launched unsuccessfully on a single Pegasus rocket in November 1996. The spacecraft achieved orbit, but the Pegasus failed to release the two satellites due to a power failure on the third stage. SAC-B was a collaborative program with the Argentines. Although primarily an engineering test of the first flight of an Argentine satellite, the mission was to use an Argentine instrument to observe hard x-rays from solar flares and use a U.S. instrument to survey diffuse x-ray emissions over a major portion of the sky. The Argentines achieved many of their engineering objectives and do not intend to build a replacement. HETE was a collaborative program with France and Japan managed by the Massachusetts Institute of Technology. The mission was to provide information about the precise location of gamma-ray bursters and spectral analysis of these and other high energy transient phenomena. NASA is currently considering a potential HETE recovery mission, which would use existing designs and hardware.

The Space Very Long Baseline Interferometry (SVLBI) program is composed of the Japanese VSOP and Russian Radioastron missions. These two international missions will provide the highest resolution images of radio sources ever obtained. NASA is participating on the science advisory groups and providing ground processing hardware, tracking support, and the construction of four ground science stations to support both missions. With its extremely long baseline, VSOP and Radioastron will explore very small radio sources with high angular resolution, thereby achieving higher resolution of active galactic nuclei and compact radio sources than can be achieved on the ground. VSOP and Radioastron each have a design life of 3 years.

The ESA XMM satellite will have highly sensitive instruments providing broad-band study of the x-ray spectrum. This mission will combine 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. is providing components to the Optical Monitor (OM) and RGS instruments. XMM science will be complementary to the U.S. Advanced X-ray Astrophysics Facility (AXAF). XMM's higher through-put (i.e., higher number of photons collected) will allow somewhat better spectroscopy of faint sources, while AXAF will excel at high resolution imaging. XMM has a lifetime goal of 10 years.

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, e-/e+ 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 2001; **INTEGRAL** has a design life of two years.

## MEASURES OF PERFORMANCE

### Tethered Satellite System:

| | |
|---|---|
| TSS launch<br>Plan: February 1996<br>Actual: February 1996 | Operations conducted aboard Shuttle mission STS 75. |

### Astro-E:

| | |
|---|---|
| Engineering model spectrometer delivery<br>Plan: April 1996<br>Actual: April - October 1996 | With the delivery of this unit, the construction and test procedures needed for the flight unit have been validated. The unit provided to the Japanese served to test system interfaces and allow complete systems tests to be run. |
| First engineering mirror delivered to Japan<br>Plan: October 1996<br>Actual: November 1996 | With the delivery of the first mirror, the construction, assembly and test procedures have been completely demonstrated. Subsequent development of the next four mirrors will follow a known path. The Japanese will be able to test out system interfaces, conduct environmental tests, and conduct complete systems tests. |
| Flight model spectrometer delivery to Japan<br>Plan: July 1997<br>Revised: December 1997-May 1998 | This task concludes the XRS instrument construction phase and begins a period of validation, testing and calibration prior to delivery of the instrument to Japan in 1998. Expected to be completed late, with subcomponents delivered to Japan as completed, but still supports the Japanese schedule. |

**Mars Instruments:**

| | |
|---|---|
| Deliver MOx Sensor Head<br>Plan: May 1996<br>Actual: May 1996 | Provide two refurbished MOx sensor heads to Russia for spacecraft integration. |
| Spacecraft launch<br>Plan: November 1996<br>Actual: November 1996 | Launched on Russian Proton booster; failed. |

**Other Shuttle/International:**

| | |
|---|---|
| SAC-B/HETE launch<br>Plan: November 1995<br>Actual: November 1996 | Delayed pending Pegasus launch vehicle recovery. Launch failure in November 1996. |
| Cluster launch<br>Plan: November 1995<br>Actual: June 1996 | Delayed by ESA until May 1996 due to Ariane-V launch vehicle problems. Launch failure in June 1996. |
| VSOP launch<br>Plan: September 1996<br>Revised: February 1997 | Instrument/ spacecraft integration and test completed: Japanese launch. |

## ACCOMPLISHMENTS AND PLANS

Despite loss of the Italian satellite during deployment in February 1996, the TSS payload did obtain some useful data. Data analysis activities will completed in the near future.

Delivery of the engineering model Astro-E calorimeter was performed in pieces, and completed in time to support the Japanese schedule requirements. Fabrication of the flight model has begun. Verification and environmental tests will be completed in early FY 1998. Design work for the five mirrors which will be supplied to the Astro-E mission has been completed by the GSFC Mirror team, and fabrication has begun. Delivery of the first engineering model mirror to the Japanese occurred in November 1996. Delivery of the first flight mirror to the Japanese is scheduled for August 1997, and the fifth and final mirror will be delivered by December 1998. The project is on schedule for a February 2000 launch.

The First Announcement of Opportunity (AO) for international competition for observing time on the SVLBI program was released in June 1995. Initial VSOP science operations are scheduled to begin May 1997, following launch in January. XMM flight model components are to be shipped by June 1997 in support of a launch in December 1999.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### EXPL PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Advanced Composition Explorer.. | 18,500 | 18,700 | 5,500 |
| Far Ultraviolet Spectroscopic Explorer | 56,600 | 22,000 | 26,800 |
| Medium Explorers | 13,700 | 41,200 | 62,400 |
| Small Explorers | 33,700 | 35,000 | 37,800 |
| University Class Explorers | 3,000 | 2,400 | 4,200 |
| Explorer Planning. | 6,700 | 5,700 | 6.000 |
| Total | 132.200 | 125.000 | 142,700 |

* Total cost information is provided in the Special Issues section

### PROGRAM GOALS

The goal of the Explorer program is to provide frequent, low-cost access to space for Physics and Astronomy investigations that can be accommodated with small to mid-sized spacecraft. The program supports investigations in all space physics and astrophysics disciplines. Investigations selected for Explorer projects are usually of a survey nature, or have specific objectives not requiring the capabilities of a major observatory. The Explorer program continues to seek reductions in the cost of developing spacecraft, in order to provide more frequent launch opportunities for space science missions.

### STRATEGY FOR ACHIEVING GOALS

Explorer mission development is managed within an essentially level funding profile. New mission starts are therefore subject to 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. As part of NASA's efforts to reduce the cost of Explorer missions, no new Delta-class missions are budgeted. NASA also funds a technology development program within the Explorer program, with the goal of reducing the weight and cost of future small spacecraft. Funding for Explorer mission studies is also provided within the Explorers budget.

**Delta Class**

The final Delta-class mission still in development, the Advanced Composition Explorer (ACE),was initiated in November 1993,and is scheduled for launch no later than December 1997. This space physics mission will use nine instruments to study the

composition of the solar corona, interplanetary and interstellar media, and galactic matter across a wide range of plasma phenomena. The instruments include six high-resolution spectrometers, designed to have better collecting power than previous systems, to study the mass and charge of plasma phenomena. Three other instruments will provide measures of the lower energy phenomena related to the solar wind. Spacecraft development of ACE is provided by the Johns Hopkins University Applied Physics Laboratory, with project management by GSFC. Foreign participation on ACE includes the University of Bern which will provide instrument components, and the Max Planck Institute which will provide a flight data system shared by three instruments.

**Medium Class**

The new Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in the areas of astrophysics and space physics. Plans call for about one MIDEX mission to be launched per year, with development cost capped at no more than $70 million (FY 1994 dollars) each, excluding the costs of the launch vehicle and mission operations and data analysis. In March 1996 NASA selected the first two science missions for the new MIDEX program. The two missions selected for definition studies leading to confirmation and development are the Microwave Anisotrophy 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 will be 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 steam 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.

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission, previously planned as a Delta-class mission, was restructured in order to reduce costs and accelerate the launch date from CY 2000 to late CY 1998. Although not a MIDEX mission, FUSE can be seen as a transitional step towards the MIDEX program. FUSE will 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 has been selected by JHU as the spacecraft developer. Canada will provide the fine error sensor assembly, and France will provide holographic gratings. GSFC will provide management oversight of this Principal Investigator-managed mission.

**Small Class**

Small Explorers (SMEX) include the Fast Auroral Snapshot (FAST), the Submillimeter Wave Astronomy Satellite (SWAS), the Transition Region and Coronal Explorer (TRACE) and the Wide-field Infrared Explorer (WIRE) missions. These missions will launch aboard Pegasus launch vehicles. These SMEX missions are managed by GSFC, where the spacecraft are developed in-house. SMEX missions are capped at $35 million in FY 1992 dollars.

The Fast Auroral Snapshot (FAST) Small Explorer initiated development in 1991 and launched successfully in August 1996 aboard a Pegasus XL launch vehicle. FAST is providing high resolution data on the Earth's auroras and on how electrical and magnetic

forces control them. The flow of electrons, protons, and other ions is being studied with greater sensitivity and spatial discrimination and faster sampling than ever before, using five small, university-provided instruments. FAST data is integrated with the results of other Earth-observing satellites and ground observations.

The Submillimeter Wave Astronomy Satellite (SWAS) Small Explorer initiated development in 1991. The launch of the SWAS mission was delayed from January 1997 to TBD due to the recent (November 1996) failure of the Pegasus launch vehicle. SWAS will provide 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. Major participants include the Smithsonian Astrophysical Observatory, the Millitech Corporation, Ball Aerospace, and the University of Cologne, which provides a spectrometer.

The Transition Region and Coronal Explorer (TRACE) Small Explorer initiated development in October 1994 and is scheduled for launch in late 1997. TRACE is a solar science mission that will explore the connections between fine-scale magnetic fields and their associated plasma structures. Observations of solar-surface magnetic fields will be combined with observations showing their effects in the photosphere, chromosphere, transition region and corona. Major participants include the Lockheed Palo Alto Research Laboratory and the Harvard-Smithsonian Center for Astrophysics.

The Wide-field Infrared Explorer (WIRE) Small Explorer also initiated development in October 1994, and is scheduled for launch in late 1998. **WIRE** will detect starburst galaxies, ultraluminous galaxies, and luminous protogalaxies. Major participants in WIRE include Utah State University, Ball Aerospace, Comell University, Cal Tech, and the Jet Propulsion Laboratory.

NASA will release an Announcement of Opportunity (OA) in 1997 to select the SMEX missions for launch in 2000 and 2001.

### University Class

University-class Explorer (UNEX) missions are currently planned to help NASA achieve a higher future flight rate. UNEX are 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. UNEX missions will cost only a few million dollars each for definition, development, and operations. UNEX missions will be similar to the Student Explorer Demonstration Initiative (STEDI) missions (SNOE, TERRIERS, and CATSAT) which are under development.

## MEASURES OF PERFORMANCE

### Advanced Composition Explorer (ACE)

| | |
|---|---|
| Instrument deliveries complete<br>Plan: December 1996<br>Actual: October 1996 | All instruments ready for physical integration with the spacecraft. |
| Begin environmental tests<br>Plan: February 1997 | Following completion of integration, the spacecraft enters its series of electrical, magnetic, vibration, thermal/vacuum, and balance tests. Ahead of schedule. |
| Ship to KSC<br>Plan: July 1997 | Spacecraft system level testing successfully complete. Move to KSC for integration with Delta II launch vehicle. Ahead of schedule. |
| Launch<br>Plan: December 1997 | Possible earlier launch. |

### Far Ultraviolet Spectroscopy Explorer (FUSE)

| | |
|---|---|
| Mission CDR<br>Plan: April 1996<br>Actual: April 1996 | Confirmed that the mission design is sound. |
| Spacecraft CDR<br>Plan: June 1996<br>Actual: June 1996 | Confirmed that design is of sufficient maturity and detail, and is compatible with established interfaces (thermal, structural, etc.). Design frozen prior to initiation of full-scale hardware fabrication. |
| FUSE Spacecraft I&T<br>Plan: June 1997 | Begin to assemble and test major components. On schedule. |
| Launch<br>Plan: October 1998 | On schedule. |

### Medium-class Explorer Progam

| | |
|---|---|
| Step 2 Selections<br>Plan: March 1996<br>Actual: April 1996 | Two missions selected for start of Phase B definition studies. |

| | |
|---|---|
| IMAGE PDR<br>Plan: January1997 | Approve for more detailed design analysis, and confirm that science objectives are achievable. On schedule |
| IMAGE Spacecraft CDR<br>Plan: August 1997 | Confirmation that the mission design is sound, and that it can move to full-scale development. On schedule. |
| IMAGE - Begin instrument I&T<br>Plan: February 1998 | Integrate and test major instrument components. On schedule. |
| IMAGE - Begin S/C System I&T<br>Plan: August 1998 | Integrate and test major spacecraft subsystems. On schedule for launch by the first quarter of FY 2000. |
| MAP Mission PDR<br>Plan: January 1997 | Confirmation leading to Phase C/D. On schedule. |
| MAP Mission CDR<br>Plan: July 1997 | Confirmation that the mission design is sound. On schedule. |
| MAP - Begin Instrument I&T<br>Plan: October 1997 | Integrate and test major instrument components. On schedule for launch by the first quarter of FY 2001. |

**Small-class Explorer Progam**

| | |
|---|---|
| Transition Region and Coronal Explorer (TRACE) Start integration and test<br>Plan: August 1996<br>Actual: August 1996 | Begin to assemble major components onto the spacecraft. |
| Ship TRACE to launch site<br>Plan: September 1997 | Move to KSC for integration with the launch vehicle. On schedule. |
| TRACE Launch<br>plan: October 1997 | On schedule, but depends on Pegasus return to flight. |

| | |
|---|---|
| Wide-field Infrared Explorer (WIRE) Start integration and test<br>Plan: October 1997 | Begin to assemble major components onto the spacecraft. On schedule. |
| WIRE Launch<br>Plan: August 1998 | On schedule, but depends on Pegasus return to flight. |

**University-class Explorer Progam**

| | |
|---|---|
| Release of AO<br>Plan: 2nd Qtr FY 1997 | Release an Announcement of Opportunity (AO) for the first round of UNEX missions. |
| Complete selection<br>Plan: 4th Qtr FY 1997 | Select the first round of UNEX missions and initiate development activities. |
| First UNEX mission launch<br>Plan: 4th Qtr FY 1999 | Launch the first UNEX mission aboard an Ultra-Lite Class ELV. |

**ACCOMPLISHMENTS AND PLANS**

ACE spacecraft integration and test started in the summer of 1996. All instruments were delivered to the spacecraft for integration during the latter part of FY 1996 in support of launch no later than December 1997.

Following successful completion of the preliminary design and non-advocate reviews, development of the restructured FUSE mission began in December 1995. A Mission Critical Design Review (CRD) was completed in April 1996, and the Spacecraft CDR was completed in June 1996. Fabrication of the spacecraft and instruments will start in February 1997, leading to integration and test activities in the summer of 1997. The FUSE spacecraft will be delivered to the launch site for final preparations to support launch in October 1998 aboard a Delta 7300s launch vehicle.

The first MIDEX Announcement of Opportunity (AO) was released in March 1995. In Step One of the evaluation process, thirteen proposals were selected in September 1995 for further evaluation. In Step Two of the evaluation process, two of the thirteen proposals were selected for definition study in April 1996. The two missions selected are MAP and IMAGE. Development for these two MIDEX missions starts in FY 1997. Confirmation for development for the IMAGE mission is expected in March 1997, and confirmation of the MAP mission is scheduled for July 1997. Development of the IMAGE and MAP missions will continue throughout FY 1998, including integration and testing of subsystems with the spacecraft structure. IMAGE is targeted for launch

in early FY 2000, and the MAP is targeted for an early FY 2001 launch. Both MAP and IMAGE will be launched aboard Med-Lite class launch vehicles. An Announcement of Opportunity (AO) will be released for the next round of the MIDEX program in March 1997.

In the SMEX program, FAST launched successfully in August 1996. SWAS will be launched as soon as possible, following the return to flight status of the Pegasus XL launch vehicle. The development of components for the TRACE and WIRE missions was completed in FY 1996. TRACE launch is scheduled in late 1997, and WIRE launch is scheduled for late 1998, both aboard Pegasus XL launch vehicles. An Announcement of Opportunity (AO) will be released for the next round of the SMEX program in January 1997.

NASA has used the additional FY 1996 UNEX appropriations provided by Congress to fund the Cooperative Astrophysics and Technology Satellite (CATSAT) mission. Additional resources required to fully fund the CATSAT mission have been provided within the Explorers FY 1997 budget. The CATSAT mission was considered as a backup to the first two Student Explorer Demonstration Initiative (STEDI) missions. CATSAT is a small, astrophysics space flight mission specifically designed to solve the puzzle of Gamma Ray Bursts' origin using an innovative multi-observation approach. The development efforts for the CATSAT spacecraft and launch vehicle started in FY 1996, and will continue through FY 1998. CATSAT is developed by the University of New Hampshire. CATSAT is targeted for launch in mid-FY 1998 aboard an Ultra-Lite class ELV.

The University Class Explorer (UNEX) program also initiates in FY 1997. NASA plans to release an Announcement of Opportunity (AO) for the UNEX program in 1997, with the first set of missions selected by the end of the fiscal year. The first of these missions will be developed in FY 1998, and is planned for launch in 1999 aboard an Ultra-Lite class ELV.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### DISCOVERY PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Near Earth Asteroid Rendezvous* | 8.300 | -- | -- |
| Mars Pathfinder * | 33.700 | -- | -- |
| Lunar Prospector * | 36,400 | 19,800 | -- |
| Stardust * | 13,500 | 52,200 | 42,300 |
| Future Missions | 10.300 | 4,800 | 64,200 |
| Total | 102,200 | 76,800 | 106,500 |

* 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 reduce total mission/life cycle costs and improve performance by using new technology and by controlling design/development and operations costs. A Discovery mission development cost (Phase C/D through launch plus 30 days) must not exceed $150 million (FY 1992 dollars), and the mission must launch within 3 years from start of development. The program also seeks to enhance public awareness of, and appreciation for, space exploration and to provide educational opportunities.

## STRATEGY FOR ACHIEVING GOALS

The Near Earth Asteroid Rendezvous (NEAR)mission was an FY 1994 new start, and was developed in-house at the Applied Physics Laboratory (APL), although many subsystems were subcontracted. NEAR was successfully launched on a Delta II launch vehicle on February 17,1996. NEAR 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 EROS launch opportunity required an accelerated development schedule for NEAR of only 27 months. The spacecraft carries five scientific instruments. The Multispectral Imager (MSI) will provide global imaging coverage as well as detailed views of the asteroid at resolutions as high as one to two meters to reveal details of the geologic processes that have affected its evolution: the X-Ray/Gamma-Ray Spectrometer (XGRS)will provide a chemical analysis by measuring several dozen key elements: the Near Infrared Spectrometer (NIS) will determine the mineral composition of the asteroid's surface: and the Magnetometer, together with radio science, will help

characterize its internal structure. The Laser Altimeter (LIDAR) will help determine the shape of the asteroid, distinguish albedo from topographic variations, and measure surface morphology. Tracking and navigation support is being provided by JPL.

The Mars Pathfinder mission was also an FY 1994 new start as an in-house effort at the Jet Propulsion Laboratory (JPL). Pathfinder was successfully launched in December 1996 and will arrive at Mars on July 4, 1997. The mission is designed to demonstrate the cruise, entry, descent, and landing system approach that will be used in future missions to place small science landers on the Martian surface. Pathfinder carries three science instruments and a microrover. The multispectral stereo Imager for Mars Pathfinder (IMP) will characterize the Martian surface morphology and geology at a 1-meter resolution. An Alpha-Proton X-ray Spectrometer (APXS) will obtain information on the elemental composition of Martian rocks and soil. This instrument is carried aboard the microrover. An Atmospheric Structure Instrument and Meteorology package (ASI-Met) will obtain information on the structure of the Martian atmosphere from measurements during entry and descent, and will obtain in-situ meteorology information while deployed on the Martian surface. The lander will also deploy and operate the microrover flight experiment to evaluate the effects of the Martian surface conditions on the rover design and its ability to deploy and operate science instruments. Portions of the science instruments were provided by Germany and Denmark.

The Lunar Prospector mission was selected as the third Discovery mission in FY 1995 with mission management from the NASA Ames Research Center. Lockheed Martin will provide the launch, spacecraft, instruments, and operations. Tracking and communications support will be supplied by the Deep Space Network. The mission is designed to search for resources on the Moon, with special emphasis on the search for water in the shaded polar regions. In addition, the mission will provide accurate gravity and magnetic models of the Moon, supplement the surface data collected by the Galileo and Clementine missions and provide major additions to our understanding of the origin and evolution of the Earth, Moon, and Planets. The spacecraft carries four scientific instruments. The Gamma Ray Spectrometer (GRS) will provide an elemental analysis of the lunar surface by measuring several key elements: the Neutron Spectrometer (NS) will determine the abundance and distribution of hydrogen in the lunar surface which points to the possible water reservoir; the Alpha Particle Spectrometer (APS) will search for gas release events and map their distribution; and the Magnetometer and Electron Reflectometer (MAG/ER) will provide a comprehensive lunar magnetics investigation. In addition, a Doppler gravity experiment (DGE) will be conducted using the spacecraft communications system to provide a map of the lunar gravity field. Launch will be on a Lockheed Launch Vehicle-I1 in September 1997. The launch window is ten days long and repeats every month.

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory. The mission team has 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. 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 will carry three additional scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) is 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 will be launched on the Med-Lite expendable launch vehicle in February 1999 with return of the samples to Earth in January 2006.

Discovery mission development is managed within an essentially level funding profile. New mission starts are therefore subject to availability of sufficient funding in order to stay within the total program budget. Funding for mission studies is also provided within the Discovery budget.

## MEASURES OF PERFORMANCE

### Mars Pathfinder

| | |
|---|---|
| Flight qualification complete<br>Plan: December 1995<br>Actual: June 1996 | Performance testing of major elements of Entry, Descent and Landing (EDL) subsystem (airbag, aeroshell, chute, etc.) was extended to assure survivability of the payload during Mars landing. Tests completed in June 1996. |
| Pre-ship Review (PSR)<br>Plan: August 1996<br>Actual: August 1996 | Spacecraft shipped to Kennedy Space Center (KSC) in August 1996 for integration with Delta II launch vehicle. |
| Launch<br>Plan: December 1996<br>Actual: December 1996 | Development phase complete: successful launch. |

### Lunar Prospector

| | |
|---|---|
| Instrument Delivery for I&T<br>Plan: October 1996<br>Actual: November 1996 | Flight model spacecraft subsystems and instruments completed. Begin system level integration and test phase. |
| Test Readiness Review<br>Plan: November 1996<br>Actual: November 1996 | Flight System test Readiness Review ensures that the flight systems are prepared for environmental testing. |
| Launch<br>Plan: October 1997<br>Revised: September 1997 | Development phase complete: start of mission. Now scheduled for September 1997, accelerated one month, to avoid potential launch pad conflicts with Cassini. |

### Stardust

| | |
|---|---|
| System Requirements Review<br>Plan: April 1996<br>Actual: April 1996 | Ensures mission requirements can be met with current technology and expected developments. |

| | |
|---|---|
| Technical Design Review<br>Plan: October 1996<br>Actual: September 1996 | Review assured readiness to proceed with detailed design and development. |
| Preliminary Design Review (PDR)<br>Plan: October 1996<br>Actual: September 1996 | Review confirmed that proposed project baseline meets all program-level performance requirements and represents acceptable level of cost and technical risk. |
| Critical Design Review<br>Plan: June 1997 | Confirms that the project system, subsystem, and component designs are of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, with acceptable risk. Successful completion freezes the design prior to initiation of fabrication, integration, and test. On schedule. |
| Start Spacecraft Assembly and Test<br>Plan: January 1998 | Begin to integrate major components of the spacecraft onto the spacecraft structure. On schedule. |
| Start environmental tests<br>Plan: June 1998 | Begin tests to demonstrate that the assembled spacecraft can withstand the launch and space environments. On schedule. |

## ACCOMPLISHMENTS AND PLANS

NEAR launched successfully in February 1996.

The assembled Mars Pathfinder spacecraft was delivered to the launch site in August 1996 and successfully launched by a Delta II vehicle in December 1996.

The Lunar Prospector Phase B design activities were completed in October 1995. A successful Technical Design Review was conducted at the end of Phase B, prior to initiating Phase C/D. Orders for procurement of major subsystems have been completed. Fabrication and integration of the scientific instruments began in September 1996. Integration and test of the complete spacecraft is planned to be completed by May 1997. Launch readiness has been accelerated one month to September 1997, in order to avoid a potential launch pad conflict with Cassini in October.

The Stardust mission was selected as the fourth Discovery mission in November 1995. Phase A study activities were completed in October 1995, and Phase B analysis activities have been initiated. A technical design review was accomplished in September

1996, and the program started Phase C/D in November 1996. Assembly and test of spacecraft components will continue until late in calendar year 1997. Integration of components into the spacecraft will occur in early CY 1998, leading to the start of environmental testing late in FY 1998.

Additional resources are requested in FY 1997 and beyond to study and initiate development of future Discovery missions. Announcements of Opportunity will be released on a regular basis. An Announcement of Opportunity was released in September 1996, and proposals are currently under evaluation. FY 1997 funds will allow for Phase A studies of selected proposals, leading to a selection late this fiscal year. Detailed Phase B studies of the selected missions will begin in October, and Phase C/D development will begin later in FY 1998.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### *MARS* SURVEYOR PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Mars Global Surveyor | 58,100 | -- | -- |
| Mars Surveyor 98 Orbiter and Lander | 52,400 | 86,900 | 40,500 |
| Future Missions | 1,400 | 3,100 | 99.200 |
| Total | 111,900 | 90,000 | 139,700 |

* Total cost information is provided in the Special Issues section

## PROGRAM GOALS

Mars has been a primary focus for scientists due to its potential for past biological activity and for comparative studies with Earth. 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. A long-term goal is to perform a sample return mission, returning Mars rocks for analysis. Earlier missions will facilitate this long-range goal by identifying those areas of Mars which are most likely to contain samples of scientific importance, including (potentially) evidence of past biological activity.

## STRATEGY FOR ACHIEVING GOALS

This program began in FY 1994 with the development of the Mars Global Surveyor, an orbiter which will obtain much of the data that would have been obtained from the Mars Observer mission. The orbiter will fly a science payload, comprised of spare Mars Observer instruments aboard a small, industry-developed spacecraft. MGS was launched in November 1996 aboard a Delta II launch vehicle and placed on a trajectory to Mars. The spacecraft will arrive at Mars in September 1997, and begin mapping operations in January, 1998. This mission is to be succeeded by a series of small orbiters and landers which will make in-situ measurements of the Martian climate and soil composition. Technology developed by the Mars Pathfinder mission will be optimized to reduce lander mission costs and technical risk. An orbiter launch is planned in December 1998, a lander launch in January 1999, two launches in the February 2001 opportunity, and launches in the 2003 and 2005 opportunities. The Mars Surveyor program has been augmented in FY 1998 and beyond to permit acceleration of a sample return mission from FY 2007 to FY 2005, while maintaining the ability to develop and launch two spacecraft (an orbiter and a lander) at each opportunity through 2003.

Mars Surveyor mission development is managed within an essentially fixed funding profile. New mission starts are therefore subject to availability of sufficient funding in order to stay within the total program budget. Funding for mission studies is also provided within the Mars Surveyor budget.

**MEASURES OF**

**Mars Global Surveyor**

| | |
|---|---|
| Instrument Calibration and Test<br>Plan: December 1995<br>Actual: May 1996 | Instrument integration completed. Instruments operated under simulated flight conditions to validate/characterize performance against design specifications. Completion rescheduled to May 1996 without impact to launch. |
| Instrument deliveries<br>Plan: February 1996<br>Actual: May 1996 | Instruments begin delivery to Lockheed Martin for integration with spacecraft prior to initiation of system level testing. Completion rescheduled to May 1996 without impact to launch date. |
| System Acceptance Review<br>Plan: August 1996<br>Actual: August 1996 | Assure that flight hardware integration is complete and ready for final acceptance tests. |
| Operational Readiness Review<br>Plan: October 1996<br>Actual: August 1996 | Formal review approving test results and recommending mission launch. Schedule accelerated to August 1996. |
| Launch<br>Plan: November 1996<br>Actual: November 1996 | Launched November 7, 1996. Spacecraft in cruise mode to Mars. |

**1998 Mars Surveyor Orbiter and Lander**

| | |
|---|---|
| Preliminary Design Review (PDR)<br>Plan: March 1996<br>Actual: March 1996 | Review held in March 1996 which confirmed that the project baseline met all program-level performance requirements and represented acceptable levels of cost and technical risk. |
| Payload Confirmation Review<br>Plan: April 1996<br>Actual: April 1996 | Confirmed that tentatively selected payload can be accommodated within the spacecraft specifications. |

| | |
|---|---|
| Spacecraft Systems Critical Design Review (CDR)<br>Plan: January 1997 | Confirms that spacecraft system, subsystem and component designs are sufficiently mature, compatible with established interfaces (structural, thermal, electrical, etc.). and represent appropriate levels of cost, schedule and technical risk. On schedule. |
| Start Orbiter Integration and Test<br>Plan: May 1997 | Integrate instruments and spacecraft subsystems. On schedule. |
| Start Lander Integration and Test<br>Plan: July 1997 | Integrate instruments and spacecraft subsystems. On schedule |
| Start Lander environmental tests<br>Plan: November 1997 | Confirm that the spacecraft can tolerate the launch and mission environments that it will face. On schedule. |
| Start Orbiter environmental tests<br>Plan: November 1997 | Confirm that the spacecraft can tolerate the launch and mission environments that it will face. On schedule. |
| Ship Orbiter spacecraft<br>Plan: August 1998 | Ship to the launch site. On schedule for December 1998 launch. |

**2001 Mars Surveyor Orbiter and Lander**

| | |
|---|---|
| Release of AO<br>Plan: 3rd Qtr FY 1997 | Release an Announcement of Opportunity (AO) for Mars Surveyor 2001 mission. |
| Start mission/flight system definition<br>Plan: 3rd Qtr FY 1997 | Begin definition study for the mission and flight system |
| Science Instrument selection<br>Plan: 1st Qtr FY 1998 | Select the Science Instrument(s) to be flown on 2001 Mars Surveyor |
| Complete Phase B and start C/D<br>Plan: 3rd Qtr FY 1998 | Complete definition study and initiate the development effort. |

| | |
|---|---|
| Critical Design Review<br>Plan: 1st Qtr FY 2000 | Confirms that spacecraft system, subsystem and component designs are sufficiently mature, compatible with established interfaces (structural, thermal, electrical, etc.), and represent appropriate levels of cost, schedule and technical risk. |
| Ship Spacecraft<br>plan: 2nd Qtr FY 2001 | Ship to KSC launch site |
| Launch<br>plan: 3rd Qtr FY 2001 | Launch |

**ACCOMPLISHMENTS AND PLANS**

In FY 1996, integration and testing of the MGS spacecraft was completed and the spacecraft was delivered to the launch site for pre-launch processing. The Mission Operations System Readiness Reviews were completed, and operational readiness was confirmed. In FY 1997, the Mission Readiness, Flight Readiness, and Launch Readiness Reviews were completed and the spacecraft and launch vehicle confirmed ready for launch. MGS was launched in November 1996 and inserted onto a trajectory to arrive at Mars in September 1997.

The follow-on Mars Surveyor missions, an orbiter and a lander, will be launched in December 1998 and January 1999, respectively. Lockheed-Martin Aerospace, Denver, was selected through a competitive process as the spacecraft development contractor. The selected payloads for the orbiter include the Pressure Modulator Infrared Radiometer (PMIRR -- a part of the Mars Observer payload) and a Color Imager. A Descent Imager and a comprehensive Volatiles and Climate payload, as well as the New Millennium Microprobe (Deep Space II), have been selected for the lander. The lander will also accommodate a Russian LIDAR atmospheric instrument. The payload confirmation review was conducted in April 1996. Preliminary Design Review was held in March 1996. and the Critical Design Review is scheduled for January 1997. Integration and testing for the orbiter will begin in May 1997 and for the lander in July, 1997. The orbiter payload is scheduled to be delivered for spacecraft integration in August 1997, with the lander payload delivered for integration in November 1997.

In FY 1997, conceptual studies on the two 2001 missions will be completed. The science instruments for the missions will be selected, and technical definition studies initiated. Development is scheduled to begin in FY 1998.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### NEW MILLENNIUM PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| New Millennium Spacecr..... | 43,500 | 48,600 | 75,700 |

### PROGRAM GOALS

History has shown that the development of new technology has enabled bolder scientific investigations and has significantly enhanced the data return from all Space Science missions. In this vein, the New Millennium program has been established to precipitate a revolution in the design, development and implementation of science spacecraft and instruments for the next century. The primary objectives of the program are to provide for the infusion of new technology through the focused development and flight validation of key breakthrough technologies. Rapid development of spacecraft and instruments utilizing breakthrough technologies at a systems level will allow for micro spacecraft and micro instruments with lower mass and equivalent (or better) performance. Intelligent flight systems will be developed where navigation, data gathering and health monitoring functions can be fused with the spacecraft. The resulting microspacecraft will allow for increased flight rates on smaller, less costly launch vehicles. Intelligent flight systems and shorter flight times will translate into smaller operations staff, allowing for increased scientific capabilities of the missions, increased technological capability, and reduced life cycle costs.

### STRATEGY FOR ACHIEVING GOALS

The program will work with the science community to highlight key scientific challenges to be addressed in the new millennium. Key capabilities to meet these challenges, and the associated emerging technologies which address these capabilities, will be identified. Those technologies which contribute most significantly to ultimately achieving program goals will be selected, aggressively pursued and flight demonstrated if necessary. Current plans reflect technology demonstration missions occurring at a rate of one or more per year, beginning as early as 1998. The primary purpose of these missions will be to validate the high priority technologies needed to enable future science missions; however, where possible and cost-effective, the demonstration flights will also exploit scientific targets of opportunity.

The New Millennium program received an augmentation in FY 1998 in order to initiate aggressive technology development and demonstration efforts for deep space missions. The Outer Planetary Technology, Advanced Radioisotope Thermoelectric Generator (RTG) and Center for Integrated Space Microsystems (CISM) projects were added in order to develop, integrate, and test key technologies for revolutionary new solar system exploration vehicles. The objective is to "leap-frog" currently planned technology developments to fulfill the long-term vision of a "spacecraft on a chip", in which all electronic, power control, computational, and communications functions can be accomplished on small integrated chips. Similarly miniaturized, highly efficient technologies in areas such as power and propulsion will also be developed to be compatible with the advanced electronic design. The projects will

be managed at the Jet Propulsion Laboratory, with industry and university support, to take advantage of the Lab's unique expertise in deep space systems and microelectronics technology. The projects will be closely coordinated with other Government agency efforts. Approval for future outer planetary missions will depend on the success of these projects. **An** initial mission decision is planned for FY 2000.

By focusing on the needs of challenging space science missions from the Sun to the outer solar system, including intensive remote and in-situ exploration and sample return, the program will provide the motivation for stretching technology development to the point of "breakthrough". In addition to the goal of ultra-low mass, emphasis will be placed on advances in autonomous operations, long lifetime, low power consumption, and survivability in extreme thermal and radiation environments. These are areas in which industry is not investing due to the lack of immediate economic incentives; however, the fundamental technological advances that are developed under this program will, when transferred to industry, provide a springboard to a variety of new commercial products and perhaps to an entirely new generation of microdevices and spacecraft.

With their focus on revolutionary mid- and far-term technologies, the Outer Planetary Technology, RTG and CISM programs will complement and will be closely coordinated with the ongoing New Millennium program. Together, these technology programs represent an investment that will give not only NASA Space Science, but also the nation's satellite, computer, and electronic industries, a head start into the 21st Century.

In implementing the strategy, NASA will place a strong emphasis on innovative management approaches assuring synergistic teaming with industry, academia, and other government agencies. The Jet Propulsion Laboratory will manage program implementation.

## MEASURES OF PERFORMANCE

### Defined Deep Space Missions

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| Deep Space (DS) Mission II Design Review<br>Plan: February 1996<br>Actual: February 1996 | Initial Deep Space (DS) II system level design and technologies identified. |
| DS Mission I Project Review<br>Plan: April 1996<br>Actual: May 1996 | Peer review of complete system and subsystem designs, ready for Detailed Design Concurrence and fabrication. |
| DS Mission I Implementation<br>**Plan:** May 1996<br>Actual: May 1996 | Award contract for fabrication, assembly, test and operations of DS I. |

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| Select technology partners<br>Plan: August 1996<br>Actual: August 1996 | Refresh integrated product development teams with new industrial partners who are developing revolutionary technologies. |
| DS II Project Review #2<br>Plan: March 1997 | Detailed system level design and technologies identified. On schedule. |
| DS I Start of ATLO<br>Plan: June 1997<br>Current: April 1997 | Start assembly, test, and launch operations of DS I. On schedule. |
| DS II Ship to STV<br>Plan: December 1997 | Ship micro-probe to solar thermal vacuum chamber. On schedule. |
| Launch DS I<br>Plan: July 1998 | First New Millennium technology demonstration flight. On schedule. |
| Launch DS II<br>Plan: January 1999 | Piggyback on Mars 98 Lander. On schedule. |

**Outer Planetary Technology, Advanced RTG and Center for Integrated Space Microsystems (CISM) projects**

| | |
|---|---|
| Testbed demonstration<br>Plan: 3rd Qtr 1997 | Conceptual demonstration of key hardware and software technologies for low-cost outer solar system missions. Supports full mission simulation by mid-1998. |
| Ultra-low power technologies<br>Plan: 4th Qtr 1998 | Micro-electronics technologies that operate at minimum power consumption: breadboards developed and integrated into advanced testbed. Developed by CISM. |
| Advanced power conversion technology<br>(RPS Phase 1)<br>Plan: 4th Qtr 1998 | High-efficiency power conversion technology coupled to existing heat source. Joint development with Department of Energy. Enables power production for first outer solar system missions with minimum mass and radioisotope content. |
| Micro-avionics modules<br>Plan: 3rd Qtr 1999 | CISM development of three-dimensional multi-chip modules to perform most spacecraft electronic functions. |

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| "Flight-like" model demo: X2000<br>Plan: 4th Qtr 1999 | X2000 integrated advanced spacecraft system (spacecraft hardware, software, mission operations) demonstrated in testbed. |
| "18 month launch ready"<br>Plan: 4th Qtr 1999 | Committment that first advanced-technology spacecraft can be ready for launch to an outer solar system target within 18 months of decision to proceed. |
| Advanced micro-electronics technologies<br>Plan: 2001-2002 | CISM development of reconfigurable and evolvable micro-electronic systems: enables robust, autonomous spacecraft at very low mass. |
| Advanced power system (RPS Phase 2)<br>Plan: 2003 | Modular, high-efficiency power source incorporating new heat source design for drastically reduced mass and radioisotope content. |
| "Flight-like" model demo: X2003<br>Plan: 2003 | Testbed demonstration of X2003, the second integrated advanced spacecraft system. Requires a major fraction of electronic functions to be performed on a small number of multi-chip modules. |
| "Spacecraft-on-a-Chip"<br>Plan: 2006 | Testbed demonstration of integrated advanced spacecraft system in which all electronic functions are performed on chips. Incorporates all advanced electronic and power technologies along with CISM-developed novel computing concepts. |

## ACCOMPLISHMENTS AND PLANS

The emphasis in 1996 was on ensuring that the technologies needed for the first mission (DS I) were on schedule and would meet the program goals. DS I hardware and software procurements, hardware fabrication and subsystem testing in support of the 1998 launch were initiated. The design for DS Mission II was completed.

The principle activities in FY 1997 include the completion of DS I spacecraft fabrication and assembly, as well as the integration and test of the new subsystem technologies associated with the mission. The majority of early analysis and test for DS II will be Completed and fabrication of flight hardware will begin.

The principle mission-related activities in FY 1998 will include the DS I launch in July, and fabrication and start of Assembly, Test, and Launch Operations (ATLO) of DS II. The DS II will piggyback on Mars 98 Lander, which is scheduled to launch in January, 1999.

Following some cost growth from the initial cost estimates provided previously, the DS I and DS II missions have been capped at $139.5 M and $26.5 M, respectively.

For Outer Planetary Technology, RTG, and CISM, the principal activities in FY 1998 will include the development of micro-electronics technologies that operate at minimum power consumption, as well as high-efficiency power conversion technologies coupled to existing heat sources. By end of FY 1999, the development of the three-dimensional, multi-chip modules are expected to be complete. The first version of the advanced testbed (the "X2000") integrating all of the above is expected to be fully integrated and lab-tested by the beginning of the year 2000, and it will be continually updated as the technologies continue to mature.

## A OF FY 1998 FUNDING REQUIREMENT

### ADVANCED SPACE TECHNOLOGY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Spacecraft systems technology. | 43,300 | 37,700 | 42,000 |
| Instrument/sensing technology | 51,800 | 39,100 | 49.600 |
| Autonomy and operations | 13,300 | 27,100 | 26,600 |
| Telerobotics | 19,500 | 14,600 | 17,600 |
| Communications | 15.400 | 13,500 | 15.400 |
| Total | 143.300 | 132,000 | 151.200 |

### PROGRAM GOALS

The future of NASA space science missions will largely be determined by the ability of NASA to reduce mission costs without reducing performance and payoffs. The exploitation of new technologies is critical to cutting costs while maintaining or enhancing mission capabilities.

The Advanced Space Technology program has the primary goal of providing innovative technologies **to** enable ambitious future space missions and to support development of the required space technology base in the **U.S.** space industry through focused, joint technology efforts. Although managed by the Space Science enterprise, the Advanced Space Technology program will address joint space technology efforts across all of the Enterprises by working to develop crosscutting technology products for future planetary, astrophysics, astronomy, Earth observing, and human exploration spacecraft systems. These products will dramatically reduce costs and increase performance to enable new and more flexible missions.

### STRATEGY FOR ACHIEVING GOALS

The Advanced Space Technology program contains the crosscutting technology development efforts formerly managed by the Office of Space Access and Technology in the Spacecraft and Remote Sensing program. The emphasis in this program is on developing generic capabilities addressing the needs of more than one Enterprise, and on carrying developments only to the point where their utility is demonstrated to the customer Enterprise. The Enterprises are then responsible for funding the development effort to integrate these technologies into their unique spacecraft development projects.

The program plans to accomplish its tasks by focusing technology development on key objectives: (1) reduce the mass and increase the efficiency of spacecraft subsystems and systems to enable use of smaller launch vehicles: (2) increase on-board and

ground system autonomy to reduce overall mission operations cost: and (3) exploit micro-fabrication technology to develop miniaturized components and instruments with equal or better performance than current components and instruments.

Overall Advanced Space Technology program goals will be achieved through a balance of near-tern and far-term activities. Far-term basic research (~5-10 year horizon) will identify and exploit major new scientific and technical discoveries to enable new missions, and near-tern (< 5 year) development will be targeted to specific user needs for currently planned missions.

The Advanced Space Technology program will utilize a comprehensive technology development strategy combining ground-based and space-based efforts. As required, selected technologies will be validated in space through flight experiments on a variety of platforms, including: technology demonstration spacecraft; laboratories in orbit such as Mir or the International Space Station; spacecraft with primary science missions which have space available for experimental payloads: or dedicated, free-flying, experiment platforms. The program is closely integrated with the New Millennium Program for Space Science and Mission to Planet Earth in order to allow the fastest possible infusion of new technologies into demonstration spacecraft. Nevertheless, space demonstrations will be used only when testing in a ground-based laboratory is not appropriate or is not achievable due to the inability to accurately simulate the on-orbit environment.

In keeping with the emphasis on developing capabilities for all NASA Enterprises, the Advanced Space Technology program is structured around cross-cutting technology areas addressing all current and future NASA space missions. This structure enables the identification of technologies that can best meet NASA mission requirements across all program areas (space science, Earth science, space communications, human exploration, etc.) versus individual mission requirements. The key cross-cutting areas are spacecraft systems technology, instrument and sensing technology, autonomy and operations, telerobotics and communications.

The Spacecraft Systems Technology program funds developments in power and propulsion, materials and structures, electronics and avionics, and systems analysis. The program includes a special emphasis on integrated design techniques and fabrication methods to produce modular spacecraft incorporating microsystems and micro-instruments. The program will demonstrate advanced thermal systems as well as lightweight space power concepts and systems including batteries, and high-efficiency, low-weight photovoltaic arrays. The program will also fund development of on-board electric and high-impulse chemical propulsion systems: advanced, high-performance, low-power data management systems; improved environmental models; and compact, lightweight deployable structures.

The Instrument/Sensing Technology program is focused on reducing the size and complexity of science payloads in order to reduce the cost of future missions. The program will also emphasize development of instruments with new scientific capabilities, such as detectors and measurement systems to allow scientific measurements in new regions of the electromagnetic spectrum, and interferometer technology for unprecedented resolution of small and distant objects. Interferometry could provide direct evidence of Earth-like planets around sun-like stars.

Autonomy and Operations Technology will emphasize the insertion of new approaches to reduce the life-cycle cost of science missions. The program will emphasize on-board autonomy as well as highly intelligent ground systems to allow hands-off spacecraft operations and automated science data analysis and archiving.

In the Telerobotics program, the Mars Pathfinder mission will demonstrate operation of the first ever telerobotically operated rover on another planet. Work will also focus on enabling lower cost planetary rovers with greater capability. Telerobotics technology will also be pursued to reduce the cost of on-orbit activities such as assembly and servicing of space stations and science satellites, as well as to allow automated tending of science payloads.

In the Communications program, the strategy is to develop improved space communications technology to meet NASA science and exploration mission requirements for the 1990's and beyond, as well as to support long-term, high-risk communications needs. The program will develop advanced technology for high data rate transmission (multi-gigabit per second) for deep space and near-Earth communications systems. It will also continue efforts to stimulate the competitiveness of the U.S. satellite communications industry by developing standards, protocols, and interoperability among space and terrestrial networks.

**MEASURES OF PERFORM**

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| Complete the development of a high-efficiency (50%) Traveling Wave tube (TWT) for Ku-Band (12-14 gigahertz (Ghz)) for satellite applications<br>Plan: February 1996<br>Actual: February 1996 | By increasing TWT efficiency from 35% to 50%, power and weight requirements would be reduced, allowing significant increases in spacecraft capability or reduced launch costs. In either case, the competitiveness of the commercial satellite industry would be enhanced. |
| Cryogenic optical testing of an infrared telescope test-bed<br>Plan: 2nd Qtr FY 96<br>Actual: 4th Qtr FY 96 | This technology supports the Space Infrared Telescope Facility (SIRTF) as well as other missions that require lightweight, high-performance optics. The testbed has been successfully transferred to the SIRTF project. |
| Complete development of a 155-Mbps, high-efficiency, Integrated Services Digital Network (ISDN) modem<br>Plan: July 1996<br>Actual: July 1996 | Efficient digital communications systems for the National Information Infrastructure (NII)/Broad Band Global Information Infrastructure (GII) will be demonstrated. |
| Mars Pathfinder micro-rover completed and flight qualified<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | The first micro-rover spacecraft to be flown, it will pave the way for future planetary exploration missions utilizing small rover systems. |

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| Initial demonstration of a 800-gigahertz local oscillator with planar diodes for sub-millimeter astrophysics applications<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Sub-millimeter heterodyne astronomy missions will be supported by providing planar diodes that are more reliable and easier to manufacture. |
| Deliver design guidelines for electromagnetic compatibility of composite structures<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | These first guidelines for grounding and bonding composite materials will increase reliability and reduce costs for designing and building spacecraft using composites. |
| Deliver design guidelines for safety-critical circuits<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | These guidelines will provide the first common basis for design and analysis of safety-critical circuits, reducing costs and improving designs. |
| Demonstrate a high-performance integrated "camera-on-a-chip" active-pixel sensor<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Miniature camera will reduce spacecraft size and cost for numerous Space and Earth Science applications. In addition, this low-power, low-manufacturing-cost, imaging technology relates directly to the potentially high-volume markets such as home and digital commercial video, computer imaging, and medical imaging. |
| Test components of integrated, free-flying magnetometer "spacecraft-on-a-chip"<br>Plan: 4th Qtr FY 1996<br>Actual: 4th Qtr FY 1996 | Multiple, very small (silver dollar size) independent sensor systems, (with sensor, data telemetry and battery power integrated onto single, chip-sized spacecraft) that can acquire science data and relay it back to a primary spacecraft will be demonstrated. |
| Complete Ranger spacecraft design<br>Plan: 4th Qtr FY 1996<br>Actual: 1st Qtr FY 1997 | Multiple advanced robotics technologies, including advanced ground control, autonomous operations, telepresence control, low-cost manipulator systems, and robotic servicing technologies will be demonstrated on this flight experiment. The engineering design prototype has been completed. The first system is being redesigned as a Space Shuttle payload, instead of an expendable launch payload, to allow for the recovery and re-flight of the experiment. |

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| Conduct demonstrations of autonomous 100-acre robotic crop harvesting<br>Plan: 4th Qtr FY 1996<br>Actual: 2nd Qtr FY 1997 | Technology initially developed for planetary rovers is being transferred to industry. This work will result in a new agricultural robotics product line that will impact an international market. |
| Operate Mars Pathfinder micro-rover on surface of Mars<br>Plan: 3rd Qtr FY 1997 | As the first micro-rover to be flown, this system will pave the way for future planetary exploration missions utilizing small rover systems. On schedule. |
| Demonstrate optimized infrared detector array for astronomy and planet detection<br>Plan: 3rd Qtr FY 1997 | The array will be a 256x256-element, impurity-band conduction (IBC), arsenic-doped-silicon (Si:As) device. This technology supports missions that require high-performance, cryogenically-cooled detector arrays at wavelengths near 40 microns. On schedule. |
| Validate ultraviolet laser crystals for use in accurate remote atmospheric observation<br>Plan: 4th Qtr FY 1997 | For both aircraft and space-based missions, NASA has a need for stable, high-performance tunable lasers to measure atmospheric constituents in order to increase our understanding of ozone depletion, global warming and other climate-related topics. This program will demonstrate a differential absorption LIDAR (DIAL) for observing water vapor, ozone, cloud top heights and aerosols. |
| Flight demonstrate a micro-gyroscope with control electronics.<br>Plan: 4th Qtr FY 1997 | A microgyroscope with 10-degrees-per-hour drift rate will be demonstrated on a DC-8 flight. This technology supports control and guidance systems for micro-spacecraft, landers, and rovers. On schedule. |
| Develop small advanced monopropellant rocket<br>Plan: 4th Qtr FY 1997 | A nontoxic monopropellant chemical system with 25% greater performance than current systems will be developed to support small satellite missions. On schedule. |
| Complete development and demonstration of a refrigerator/ freezer for Space Station<br>Plan: 4th Qtr FY 1996<br>Current: TDB | This breadboard refrigerator/freezer would store biological specimens on the Space Station. Funding constraints forced delay of this effort. Completion would be managed and funded by the Space Station. |

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| Demonstrate advanced Ni-Hydrogen battery<br>Plan: 4th Qtr FY 1997 | This battery will deliver 100 watts per kilogram and have a 10-year life in LEO, approximately twice the performance of current batteries. On schedule. |
| Complete development of a 20-GHz System-Level Integrated Circuit (SLIC)/Monolithic Microwave Integrated Circuit (MMIC) 4-element phased array antenna system<br>Plan: September 1996<br>Current: July 1997 | This work will support the satellite industry in developing less expensive satellite antennas. |
| Reduce size and weight of a communication system by 2-3 times.<br>Plan: 4th Qtr FY 1997 | Reductions will be achieved by integrating an advanced, space-based 20-Ghz phased-array antenna system in a communications network. On schedule. |
| Complete development of a high-efficiency modem for satellite applications<br>Plan: 3rd Qtr FY 1997 | The new asynchronous transfer mode device will transmit 155 million bits per second in hybrid space/terrestrial systems to provide efficient digital communications systems for the National Information Infrastructure (NII)/Broad Band Global Information Infrastructure (GII). On schedule. |
| Pulse Plasma Thruster (PPT)<br>Plan: 2nd Qtr FY 1998 | Deliver insertion-class PPT for joint NASA/Air Force flight demonstration of this technology, which is important for orbit transfer and maintenance functions. On schedule. |
| Develop wide-band low-power electronically-tuned local oscillator sources up to 1.3 THz<br>Plan: 3rd Qtr FY 1998 | This technology supports planned astronomy missions such as the Far Infrared and Submillimeter Space Telescope (FIRST) mission to spectroscopically measure the chemical, make-up of interstellar gasses and nebula. On schedule. |
| Provide and fly robotic sample acquisition manipulator for the Mars Surveyor mission<br>Plan: 3rd Qtr FY 1998 | Advanced robotics technologies allow this sample acquisition manipulator to exceed the capabilities of the Viking lander manipulator, while occupying less than 20% of the mass and 20% of the stowed volume of that manipulator. |

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| Conduct on-orbit Ranger telerobotic fight experiment<br>Plan: 4th Qtr FY 1998 | This experiment will demonstrate multiple on-orbit robotic servicing capabilities, relevant to science payload servicing and Space Station assembly and maintenance. On schedule. |
| Develop a small advanced monopropellant rocket engine<br>Plan: 4th Qtr FY 1998 | Fabricate and test flight-type nontoxic monopropellant system developed in FY 97. On schedule. |
| Demonstrate 25% efficient production-quality solar cells<br>Plan: 4th Qtr FY 1997<br>Current: 4th Qtr FY 1998 | Pilot production of these efficient, new multi-band gap, large format solar cells will be done in FY 98. On revised schedule. |
| Advanced flight computer program<br>Plan: 4th Qtr FY 1998 | Deliver ultra low power electronics hardware to the New Millennium DS-1 spacecraft program. On schedule. |

## ACCOMPLISHMENTS AND PLANS

### Spacecraft Systems Technology

In FY 1996, the Spacecraft Systems Technology program focused on smaller, more efficient, lower-cost sub-systems and systems. The on-board propulsion program demonstrated a small, pulsed-plasma, electric propulsion system for efficient orbital position and trajectory control of small spacecraft, and conducted a performance demonstration of a non-toxic monopropellent chemical system. Advanced photovoltaic cells with 24% efficiency were demonstrated and a program exploring dynamic energy storage was initiated. Studies were also initiated on advanced energy conversion methods to reduce the amount of radioisotope needed for deep space missions by up to 5 times. Low temperature electronic power system components were characterized at very low temperatures (~ 10 degrees K) for operation in very harsh deep space environments. In space data systems, a 3-D stacked, multi-chip, 1 Gbit, solid state memory module was built to replace data recorders. It is 10 times lighter and smaller than current systems.

In FY 1997, the spacecraft systems technology program element is continuing to focus on increasing the performance of spacecraft systems by at least 2 times, while decreasing mass and volume by 2-3 times and cutting costs about 2-3 times over the best available current systems. The on-board propulsion program will continue development of high-efficiency electric propulsion technology for orbital insertion and maintenance. Electric propulsion technology can reduce trip times for deep space missions by 3 times. The space power program will demonstrate battery technology to double the life of current batteries in LEO and

photovoltaic technology to increase efficiency by 40%. Combined with lightweight array technology, this effort will lead to systems capable of about 300 W/kg at about one-third the cost of current systems. A breadboard model of an advanced, low-vibration, low-power refrigerator/freezer for use on the International Space Station will be demonstrated. The flight data systems program will demonstrate a complete 3-D stacked, multi-module avionics architecture that is 10 times smaller than current spacecraft avionics systems. In addition, guidance/navigation algorithms will be validated for autonomous cruise and maneuver control.

In FY 1998, within the cross-cutting technology arena of power, efforts on photovoltaic concentrators with advanced concentrator cells, optics, and arrays, will lead to the first operational space flight of this technology. The program is expected to demonstrate that these technologies provide comparable power to the best SOA solar arrays at half the cost. Efforts will continue on advanced battery developments, such as bipolar nickel metal hydride and nickel hydride, as well as on power component/management systems with the potential benefits of reduced cost, increased specific energy, increased energy density and reduced weight. Flywheel storage. systems are being researched and characterized in conjunction with U.S. companies investing private sector funds. Flywheel systems have the potential of 10-times better system performance (kW/kg) than battery systems in low-Earth orbit (LEO) due to greatly simplified power management. In the area of electric propulsion, both advanced electrostatic (ion and Hall) systems and pulsed plasma thrusters will be developed. High performance electrostatic systems are important for government and commercial orbit transfer and maintenance functions for deep space missions. Pulsed plasma thrusters are required for both the precision positioning of science spacecraft and the insertion and control of both government and commercial satellites. In chemical propulsion, efforts will concentrate on high performance bipropellant engines for both sample return missions and satellite orbit insertions and on the continued development of advanced non-toxic monopropellant systems for low-cost science and commercial spacecraft. Miniature systems for small spacecraft will continue to be a priority in all areas of on-board propulsion. Miniaturization of spacecraft electronic systems offers the potential to revolutionize most space exploration missions. Low-power systems, including ultra-low-power CMOS micro-power management and distribution systems designed for low-power switching and low-power synthesis, will be developed and delivered for on-orbit flight demonstration. Highly integrated reliable, low-power, non-volatile data storage, such as holographic storage, will be developed and demonstrated.

**Instrument/Sensing Technology**

In FY 1996, the program continued to work with industry, universities, and other government laboratories to develop instrument technologies for Earth and planetary science, astrophysics and space physics applications. These technologies include development of cooled and uncooled large-format infrared, as well as visible, ultraviolet, x-ray, and high-energy detector arrays. For sensitive astrophysics observations in the submillimeter region of the electromagnetic spectrum, an 800 GHz submillimeter mixer was demonstrated in FY 1996.

Micro-electro-mechanical systems (MEMS) technology was utilized in several FY 1996 efforts: a prototype package for a Mars/Earth upper atmosphere micro-weather station was completed: a high-performance, integrated "camera-on-a-chip" active pixel sensor for miniature imaging systems was demonstrated: and the components for an integrated free-flying magnetometer "spacecraft-on-a-chip" were tested.

Also in FY 1996, a technology testbed for an advanced infrared telescope with twice the collecting area, half the mass, and one-third the diffraction-limited wavelength of the previously flown Infrared Astronomy Satellite (IRAS) was completed at the JPL cryogenic optical test facility. Cryogenic optical testing was completed and the technology has been successfully transferred to the SIRTF project.

The program also increased emphasis in 1996 on developing sensor and instrument technology for compact, low-cost space radar systems that can be used with small spacecraft (incorporating deployable arrays) to increase the spectrum of space-based Earth or planetary observations.

In FY 1997, Instrument/Sensing technology will continue to focus on expanded spectrum performance and micro-miniaturization for both Earth and space science. Program emphasis will be increased in the areas of space Interferometry to support ultrahigh resolution astronomy missions and extra-solar planetary exploration programs. The development of sensor and instrument technology for compact, low-cost space radar systems continues in FY 1997 with the goal of enabling a low-cost flight demonstration of lightweight synthetic aperture radar technology. The program will also support deployable concepts for highly efficient packaging of solar arrays, optics, etc. to enable spacecraft with large collecting surfaces to be launched in smaller launch vehicles. A very high frequency (2.5Thz) submillimeter receiver will be demonstrated to measure a component of the upper atmosphere ozone chemistry that currently cannot be monitored from space.

In FY 1998, emphasis will continue on micro-electro-mechanical systems technology needed to fabricate new-generation sensors, actuators, and integrated micro-instrument systems. NASA will demonstrate improved prototypes of MEMS-based microthrusters, components for guidance control, radio frequency (RF) switches, microresonators, and microvalves as it continues to improve performance-to-cost ratio as well as reduce size, weight, and development cycle time over conventional counterparts. Low-cost, accurate microsensors for in-situ measurement systems are needed to support new atmospheric research programs. Technology will be developed to support this activity through deployable instruments for field and operational testing with network lander systems. Submillimeter heterodyne astronomy missions will be supported by providing planary diodes that are more reliable and easier to manufacture. Wide-band, low-power, electronically-tuned local oscillator sources to 1300 Ghz will be developed for astrophysics applications such as the European Space Agency's Far Infrared and Submillimeter Space Telescope (FIRST). This technology will enable spectroscopic measurement of the gases that make up interstellar nebulae.

**Autonomy and Operations**

In FY 1996, the operations program focused on reducing overall mission costs by improving spacecraft and ground systems. The program encompassed artificial intelligence applications to reduce direct dependence on human operators and on the people retrieving and analyzing data. This technology aims at improving the return on investment in science data and the extraction of critical information on spacecraft health from returned operating performance data. A software architecture for highly autonomous spacecraft was demonstrated. This activity included onboard command sequence development and validation for autonomous maneuvers, for science instrument control and for onboard data reduction prior to downlinking. By processing the data on board the spacecraft, the costs of data management and analysis can be reduced by a factor of at least ten.

In FY 1997, the Remote Agent architecture for the New Millennium DS-1 spacecraft will be delivered. This architecture contains an onboard planner/scheduler, an intelligent real-time fault monitoring and systems executive, that will support execution of planned sequences when responding to unexpected events. The Beacon Operations capability for the DS-1 satellite, will permit 'on-call" rather than full-time mission operations. The Beacon Operations capability downloads engineering data to permit ground personnel to identify the problem and upload a solution. Also in FY 1997, methods for advanced onboard autonomy, called the TOPEX Autonomous Maneuver Planning and Execution (TAME) experiment will be tested.

In FY 1998, the Autonomy and Operations program will implement a set of Regional Validation Centers (RVCs) which will evaluate our capability to enable a massive increase in the number of users of Earth sensing satellite data. An RVC consists of a very low-cost ground station for directly receiving satellite data, processing, archiving, retrieving and analyzing it. It will contain an advanced suite of artificial intelligence tools for data fusion, mining, analysis and visualization. We will also be developing methods for increasing the autonomy of satellites by doing onboard science data operations. This includes the ability for orbiting satellites to automatically detect and catalogue all instances of a selected entity such as small volcanoes, and reduce communications bandwidth and power requirements by downloading only the results, and not all of the data.

**Telerobotics**

In FY 1996, the Telerobotics program completed the development of the Sojourner rover, a 10-Kg microrover that will conduct operations on the surface of Mars as part of the Mars Pathfinder mission in FY 1997. At the end of the fiscal year, the completed rover was delivered to the flight program for integration into the spacecraft, on schedule and under budget. Assembly of a lunar rover testbed was completed, and initial field tests of the traverse capabilities were conducted. These field tests included 40-Km traverses of a simulated lunar surface with the rover operating under supervisory control and safeguarded teleoperation. Initial work on the development of very small "nano-rover" systems was performed, culminating in the demonstration of a 100-gram nano-rover prototype which performed the Mars Pathfinder mission scenario. This work will eventually lead to an equivalent level of capability packaged within a 10-gram, 1-cubic centimeter form factor.

In FY 1997, NASA will conduct operations of the 10-kilogram (kg) Sojourner microrover on Mars as part of the Mars Pathfinder mission. The rover will provide images of the lander to assess its condition on the planet's surface: emplace an alpha-proton-x-ray spectrometer to determine the composition of rocks and soil samples: and conduct multiple technology experiments to lead the way for routine use of small rovers to explore Mars. The program will also continue development of the next generation of planetary surface micro-rovers, targeting a 50% reduction in rover mass and volume and development of technologies for planetary and small body sample collection, preservation and autonomous analysis by FY 1998. These autonomous rover technologies will also be applied to terrestrial problems, through the Robotics Engineering Consortium. This year, the first of these developments - a robotic agricultural harvester capable of conducting field crop operations without a human driver on board - will be completed and commercialized by the industrial partners in the project. In addition, the telerobotics program will complete development of the AERCam/Sprint flight experiment, a robotic 'flying eye" for visualization and inspection of science and Space Station payloads. This system will demonstrate the use of advanced robotics technology to reduce EVA astronaut requirements for science payload servicing, and represents the first in a series of cooperative human EVA/robotic systems to be developed for on-orbit servicing operations. Management and funding of AERCAM moves to the Office of Space Flight in FY 1998.

In FY 1998, the program will complete the implementation and delivery of a robotic sampling manipulator which will be incorporated into the Mars Surveyor spacecraft, to be launched at the end of the year. This manipulator will provide a sample acquisition capability similar to that of the Viking lander, but will occupy less than 20% of the stowed volume and take less than 20% of the mass of the previous manipulator. The program will continue field tests of the lunar rover technology testbed in the Antarctic, simultaneously testing lunar rover control modes and evaluating the technology for possible applications to search operations for Antarctic meteorites. These field tests will also complete the evaluation of VEVI technology, a virtual reality-based control architecture which supports immersive display and visualization technology as the primary operator interface, permitting a more intuitive interface which minimizes operator training requirements and expands utilization of the interface data. Also, in FY 1998 the Ranger telerobotic technology experiment will be flown as a Space Shuttle payload. The experiment will demonstrate multiple advanced robotics technologies, including advanced ground control, autonomous operations, telepresence control, low-cost manipulator systems, and robotic servicing technologies.

**Communications**

In FY 1996, using high data rate terminals activated in 1995, we demonstrated satellite connectivity among super computers at a data rate of 622 Mbps. This effort enabled fast distribution of scientific data among research laboratories in the U.S. This will be the first time that such widely distributed research centers were connected through satellites.

In FY 1997, NASA and industry will work together to demonstrate wide-band communications integrating space and terrestrial systems. Standards, protocols and interoperability for a world-wide, seamless multimedia network will be developed and demonstrated. The wide-band-capable new terminals will support the first real-time, live transmissions of telescience, tele-education, and remote sensing information. Technology demonstrations will be completed that combine real-time, aeronautical and maritime, high-data-rate communications enabling communications at a rate about 10 times greater than is possible today. The advanced antenna system will use a System-Level Integrated Circuit (SLIC)/Monolithic Microwave Integrated Circuit (MMIC) 4-element phased-array antenna system in a communications network. The effort is a partnership with the satellite industry to reduce the cost of satellite phased-array antennas. A new asynchronous transfer mode device will transmit 155 million bits per second in hybrid space/terrestrial systems to provide efficient digital communications systems for the National Information Infrastructure (NII)/Broad Band Global.

In FY 1998, NASA will take the leadership to establish a testbed for seamlessly interoperable satellite and terrestrial networks to be called SPACENET. This testbed will be a continuation and expansion of NASA's effort to demonstrate hybrid networks operating at 155 millions bits per second. The focus of this testbed is to help solve the problem of seamless interoperability in satellite and terrestrial communications and to advance NASA and commercial applications in the NII/Global Information Infrastructure (GII). Many experiments will take place to demonstrate satellite unique capabilities and their potential contribution to the GII. The program will put additional emphasis in the technology development of a high data rate (above 350 Mbps) optical communications terminal for NASA and commercial applications. Many new NASA missions require the capability provided by optical communications.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### MISSION OPERATIONS AND DATA ANALYSIS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| HST operations and servicing | 190,700 | 202,000 | 163,800 |
| HST data analysis | 43,500 | 40,900 | 45,700 |
| AXAF mission operations and data analysis | 40,400 | 41,300 | 45,400 |
| GGS mission operations and data analysis | 26,500 | 25,500 | 15,700 |
| COSTR mission operations and data analysis | 31,900 | 28,400 | 8,500 |
| GRO mission operations and data analysis | 13,700 | 10,600 | 4,000 |
| Galileo operations | 71,500 | 64,400 | 29,800 |
| Cassini mission operations and data analysis | -- | -- | 38,100 |
| NEAR operations | 4,900 | 1,400 | 9,500 |
| Mars surveyor operations | -- | 16,400 | 19,600 |
| Mars pathfinder operations | -- | 9,600 | 5,800 |
| Lunar prospector operations | -- | 800 | 4,300 |
| Planetary flight support | 49,400 | 42,900 | 36,600 |
| Other mission operations and data analysis | 91,100 | 99,100 | 80,600 |
| Total | 563,600 | 583,300 | 507,400 |

### PROGRAM GOALS

The goal of the Mission Operations and Data Analysis (MO&DA) program is to maximize the scientific return from NASA's investment in spacecraft and other data collection sources. The MO&DA effort is fundamental to achieving the goals of the Office of Space Science (OSS) program because it funds the operations of the data collecting hardware and the data analysis that produces scientific discoveries. Funding supports satellite operations during the performance of the core missions, extended operations of selected spacecraft, and ongoing analysis of data after the usable life of spacecraft has expired. Funding also supports pre-flight preparations for satellite operations and data analysis activities, and long-term data archiving and data base services. Also supported are preparations for future servicing of the Hubble Space Telescope (HST), including development of advanced science instruments.

The MO&DA program is working to dramatically reduce operations 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.

Currently, 22 operational missions (23 spacecraft) are supported. Astrophysics missions include the Hubble Space Telescope (HST, 1990), the Compton Gamma-Ray Observatory (CGRO, 1991). the Rossi X-ray Timing Explorer (RXTE, 1995). the Extreme Ultraviolet Explorer (EUVE, 1992), U.S. participation in the international Roentgen Satellite (ROSAT, 1990), Japanese Astro-D/ASCA (1993), and the Infrared Space Observatory (ISO). Space physics missions include FAST (1996), Polar (1996), SOHO (19951, Wind (1994), Geotail (1992), SAMPEX (1992). Yohkoh (1991), Ulysses (1990), Voyager 1 and 2 (1977), Pioneer 10 (1972), and the Interplanetary Monitoring Platform (IMP-8, 1973). Planetary missions include Galileo (1989), the Near Earth Asteroid Rendezvous (NEAR, 1996), Mars Global Surveyor (1996), and Mars Pathfinder (1996).

## STRATEGY FOR ACHIEVING GOALS

Hubble Space Telescope (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. In a single year of operations, the activities of over 500 scientists are supported under the HST program, and over 15,000 observations are recorded. In order to extend its operational life and provide a basis for future enhancements of its scientific capabilities, HST is designed to be serviceable. This 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.

Pre-launch operations funding for the Advanced X-ray Astrophysics Facility (AXAF) program supports the development of a ground control system and a science operations center, and preparation for flight system operation. The AXAF Science Center (ASC) in Boston, developed by the Massachusetts Institute of Technology (MIT), supports x-ray calibration of the flight mirror assembly and instruments using a precursor of the AXAF data system during the pre-launch phase of the program. NASA has recently decided that AXAF operations will be conducted from a control center at the ASC, rather than at MSFC. This decision was made pursuant to the Zero Base Review team recommendation that AXAF be managed by an Institute.

Global Geospace Science (GGS) MO&DA funds two space physics missions, Wind and Polar. 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.

Collaborative Solar-Terrestrial Research (COSTR) MO&DA funds the SOHO and Geotail missions. SOHO studies the solar interior by measuring the oscillations of the surface. SOHO also investigates the hot outer atmosphere of the Sun that generates the variable solar wind and W 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 dayside of the earth. SOHO. Geotail. Wind, and Polar are the core spacecraft of the International Solar Terrestrial Physics (ISTP) program.

The Compton Gamma-Ray Observatory (CGRO)measures gamma-rays, providing unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, and supernova, as well as on the nature of the mysterious cosmic gamma-ray bursts.

Galileo is executing a series of close flybys of Jupiter and its moons, Ganymede, Callisto and Europa, studying surface properties. gravity fields, and magnetic fields. and characterizing the magnetospheric environment of Jupiter and the circulation of the Great Red Spot of Jupiter.

Cassini will launch in FY 1998 and will perform initial activities in support of the seven-year cruise to Saturn. Efforts will be underway to ensure proper trajectory through tracking and appropriate targeting maneuvers of the Cassini spacecraft. The health of science instruments will be maintained by periodic checkouts.

The Near Earth Asteroid Rendezvous (NEAR)mission was launched in February 1996, and will amve at the asteroid 433 Eros in February 1999.

Mars Surveyor operations commenced with the launch of Mars Global Surveyor in November 1996. The spacecraft will reach Mars in September 1997 and will begin maneuvers to achieve its desired mapping orbit.

Mars Pathfinder operations commenced at launch in December 1996. The spacecraft will land on Mars on July 4, 1997, and begin science operations shortly thereafter.

Lunar Prospector will begin operations after launch in September 1997.

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. The program also provides mission control, tracking, telemetry, and command functions for all spacecraft utilizing the Deep Space Network (DSN). At present, PFS supports ongoing mission operations for Voyager, Ulysses, Galileo, Mars Pathfinders, and Mars Global Surveyor. 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. The PFS program also supports the tools, personnel and policy implementation of the Resource Allocation Planning (RAP) team which collates, analyzes and identifies the conflicts associated with Deep Space Network (DSN) tracking requests in order to maximize science and mission return.

The Other MO&DA budget funds a variety of (mostly smaller) missions. RXTE uses three instruments to conduct timing studies of x-ray sources. EUVE is studying the sky at wavelengths once believed to be completely absorbed by the thin gas between the stars. U.S. observers continue to enjoy 50% of the observing time (shared with Germany and the UK) from the highly successful ROSAT X-ray satellite. The Japanese/U.S. Astro-D/ASCA spacecraft is conducting spatially resolved spectroscopic observations of selected cosmic x-ray sources. The European Space Agency's ISO mission conducts high-sensitivity spectroscopic measurements of infrared astronomy sources, with the participation of a significant number of U.S. scientists. 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. SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays. The Yohkoh spacecraft, a cooperative program with the Japanese, is continuing to gather x-ray and spectroscopic data on solar flares and the corona. Ulysses is currently studying the Sun's polar regions, measuring the interplanetary medium and solar wind as a function of heliographic latitude. Voyager 1 and 2 and Pioneer 10 are continuing to probe the outer heliosphere and look for the heliospheric boundary with interstellar space as they travel beyond the planets. IMP-8 performs near-continuous studies of the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

## MEASURES OF PERFORMANCE

### Hubble Space Telescope

| | |
|---|---|
| Cargo Integration Review for the Second Servicing Mission<br>Plan: March 1996<br>Actual: March 1996 | Completed the coordination of HST flight hardware and carriers with JSC shuttle payload integration. |
| Advanced Camera System Critical Design Review<br>Plan: April 1996<br>Actual: April 1996 | Validate design maturity in preparation for system fabrication. |
| Deliver NICMOS/STIS to GSFC<br>Plan: August 1996<br>Actual: August 1996 | Instrument development activities completed: instruments shipped to GSFC to begin final integration and testing. |
| 2nd Servicing Mission<br>Plan: February 1997 | Replace Faint Object Spectrometer (FOS) and Goddard High Resolution Spectrometer (GHRS) with Space Telescope Imaging Spectrograph (STIS): add Near-Infrared Camera and Multiobject Spectrometer (NICMOS) instrument: replace other hardware as required. On schedule. |
| On-Line Release 1<br>Plan: February 1996<br>Actual: February 1996 | First major delivery of on-line system hardware and software for integrated systems testing. |

| | |
|---|---|
| Advanced Camera System Alignment Completed<br>Plan: September 1997 | Complete optical alignment in preparation for final integration and test, prior to shipment to GSFC. On schedule. |
| Advanced Camera delivered to GSFC<br>Plan: July 1998 | Allows for final testing prior to shipment to the launch site. On schedule. |

**AXAF**

| | |
|---|---|
| AXAF Science Center End-to End CDR<br>Plan: January 1997 | Validate design maturity in preparation for ASC system development. On schedule. |
| Ground systems ready to support Integration and Test<br>Plan: July 1997 | Able to proceed with spacecraft integration and test activities. On schedule. |
| Ground System Release #4<br>Plan: December 1997 | Full functionality of ground system hardware and software. The completed system will be used by the flight operations team in CY 1998 during training before launch. On schedule. |

**Galileo**

| | |
|---|---|
| Return Probe Data<br>Plan: May 1996<br>Actual: May 1996 | All probe data sent to and stored on the orbiter transmitted to Earth. Critical element of overall mission objectives. Completed May 1996. |
| Return Io and Jupiter Encounter Data<br>Plan: July 1996<br>Actual: July 1996 | Transmit to Earth, science data and imagery from encounters with Jupiter and its moon Io. |
| Ganymede Encounter<br>Plan: July 1996<br>Actual: July 1996 | Transmit all science data and imagery from two Ganymede encounters in 1996 to Earth. Data relay was completed in July 1996. |

| | |
|---|---|
| Callisto Encounter<br>Plan: November 1996<br>Actual: November 1996 | Encounter and data playback were successfully executed. |
| Europa Encounter<br>Plan: December 1996<br>Actual: December 1996 | Execute closest ever flyby of Europa and transmit playback data. |
| Various Encounters<br>Plan: 1997 and 1998 | Execute 2 Europa, 2 Ganymede and 2 Callisto encounters and transmit playback data approximately 2 months after encounter. |

### *NEAR*

| | |
|---|---|
| Mathilde Encounter<br>Plan: June 1997 | Flyby the asteroid Mathilde, largest asteroid (60km diameter) observed by spacecraft. On schedule. |

### Mars Global Surveyor

| | |
|---|---|
| Mars orbit insertion<br>Plan: September 1997 | Bum to insert into Mars capture orbit. On schedule. |
| Initiate Mapping Operations<br>Plan: March 1998 | Initiate 2 years of science data acquisition on Mars composition, topography, atmosphere, and magnetic fields. On schedule. |

### Mars Pathfinder

| | |
|---|---|
| Mars Landing<br>Plan: July 1997 | Lander lands on Martian surface, transmits engineering and science data back to Earth. On schedule. |

### Cassini

| | |
|---|---|
| Deep Space Maneuver<br>Plan: March 1998 | Bum to target first Venus-Flyby gravity assist. On schedule. |
| Venus Flyby<br>Plan: April 1998 | First Venus flyby gravity assist. On schedule. |

## Planetary Flight Support

| | |
|---|---|
| Begin Cassini Pre-Launch Operations<br>Plan: August 1996<br>Actual: August 1996 | Initiate pre-launch software development for telemetry, command mission control, data management, and Multi-mission spacecraft analysis system in support of flight operations. |
| Mars Global Surveyor Ground System<br>Plan: August 1996<br>Actual: August 1996 | Hardware and telemetry and command software to support launch of the Mars Global Surveyor spacecraft. |
| Mars Pathfinder Ground System<br>Plan: August 1996<br>Actual: August 1996 | Complete development and testing of modifications to the Multi-mission Ground System to support launch of Mars Pathfinder mission. |
| Cassini Spacecraft Analysis System<br>Plan: October 1996<br>Actual: October 1996 | Completed development and testing of Build 2 of the Multi-mission Spacecraft Analysis System (MSAS) to support the Cassini mission. |
| Provide and update tools for the Multi-mission Ground System for all missions<br>Plan: (ongoing) | Ground system and power supply are being continuously updated to make them more robust in avoiding service interruptions as well as more cost-effective. |

## ACCOMPLISHMENTS AND PLANS

### Science results and education

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 witnessed by widespread media coverage. NASA is also finding ways to partner with the education community in order to strengthen science, technology, and mathematics education.

The Hubble Space Telescope (HST) is fulfilling the promises NASA made for it, generating an ongoing stream of major scientific discoveries. HST is creating great public interest as measured by frequent major news and television reports. HST images are also being distributed to school children nationwide through NASA's national "Teacher Resource Laboratory" system, In a comparative review of eleven astrophysics MO&DA programs, an external panel of senior scientists judged HST to have the highest science merit, based on total science as well as on a science-per-dollar basis. Hubble results in the last year include:

Two international teams of astronomers using HST reported major progress in converging on an accurate measurement of the Universe's rate of expansion -- the Hubble constant -- a value that has been debated for over half a century. The new results yield ranges for the age of the Universe from 9-12 billion years, and 11-14 billion years, respectively. The goal of the project is to measure the Hubble Constant to ten percent accuracy.

Dramatic HST images of Evaporating Gaseous Globules, or "EGGs", in the Eagle nebula (also known as M16), reveal the process of new star formation and how young hot stars limit the sizes of nearby stars that form later.

The Hubble Deep Field (HDF) image, covering a speck of the sky only about the width of a dime located 75 feet away, shows a bewildering assortment of at least 1,500 galaxies at various stages of evolution.

For the first time, astronomers have seen details on the surface of Pluto. Hubble's snapshots of nearly the entire surface of Pluto, taken as the planet rotated through a 6.4-day period, show that Pluto is a complex object, with more large-scale contrast than any planet, except Earth.

Probing the mysterious heart of the Crab Nebula, the tattered remains of a stellar cataclysm witnessed more than 900 years ago, astronomers using HST have found that the Crab is even more dynamic than previously understood, based on a cosmic "movie" assembled from a series of Hubble observations. The results promise to shed new light on a variety of high energy phenomena in the universe, from nearby neutron stars to remote quasars.

HST revealed a grouping of 18 gigantic star clusters that appear to be the same distance from Earth, and close enough to each other that they will eventually merge into a few galaxy- sized objects. They are so far away, 11 billion light-years, that they existed during the epoch when it is commonly believed galaxies started to form. These results add weight to a leading theory that galaxies grew by starting out as clumps of stars, which, through a complex series of encounters, consolidated into larger assemblages that we see as fully formed galaxies today.

HST images have shown that quasars live in a remarkable variety of galaxies, many of which are violently colliding. This complicated picture suggests there may be a variety of mechanisms -- some quite subtle -- for "turning on" quasars, the universe's most energetic objects.

The Wind spacecraft found itself immersed in a magnetic cloud for 30 hours in October 1995, and provided an unusual level of coordination among different spacecraft in the ISTP program. Wind is also conducting detailed studies of the interaction of the moon with the solar wind, and has been used in conjunction with Ulysses to triangulate type III solar bursts so that the global magnetic field in the interplanetary medium can be mapped. Wind has resolved the isotopic components of the solar and anomalous cosmic rays.

The Polar satellite has made several significant observations in its first months of operation. These include observation of complete substorms in a sequence of W and X-ray images: the observation of magnetic re-connection signatures in high latitude

particle data tailward of the polar cusps; unusually strong electric field signatures in the near-Earth horns of the plasma sheet; and the construction of mid-latitude plasma images resulting from energetic neutral atoms.

Geotail discovered that atmospheric oxygen ions far out (900,000 miles) in the Earth's magnetic tail are accelerated to extremely high speeds, in excess of a million miles an hour. The Geotail spacecraft has established the importance of flux ropes in the Earth's magnetotail. This will displace the long-accepted picture of plasmoids as an important phenomenon in the magnetotail. Geotail also detected two different types of "breathing" of the Earth's magnetotail, the "windmill effect" and "magnetospheric substorms". The "breathing" phenomenon is currently being investigated.

Galileo's atmospheric probe was released in July 1995 and successfully entered Jupiter's atmosphere shortly before Galileo was successfully inserted into Jupiter orbit December 7, 1995. The Orbiter is partially through its 23-month study of the Jovian system, and will orbit the giant planet 11 times. Galileo completed the return of the probe data as well as new science and images from Jupiter and encounters with the four Galilean satellites, Io, Ganymede, Europa and Callisto, in 1996. Among the most important discoveries are the intrinsic magnetic field of Io; the probable iron core of Io; the intrinsic magnetic field of Ganymede; the lack of an intrinsic magnetic field on Callisto; and evidence that Callisto's interior is undifferentiated. In-situ measurements during the Galileo probe's descent into Jupiter's atmosphere in December 1995 produced a wealth of results; the most significant findings are that there is much less water vapor than expected, and that winds persist much deeper into the atmosphere than expected. Galileo has also provided images of Europa that indicate the possibility of liquid water on that moon. Additional information on Europa will be provided in the data from the December 1996 Galileo fly-by, the closest encounter to date with Europa.

Ulysses has completed its historic mission over the poles of the Sun during a period of minimum solar activity, and has discovered global differences in the fast and slow solar wind from the equator to the poles. Ulysses also determined that interstellar dust does reach into the inner solar system, and that the velocity and direction of interstellar dust compares well with that of interstellar helium. Another major discovery is that the magnitude of the radial component of the Sun's magnetic field is uniform in the north and south polar regions and in the equatorial region, and that the solar wind is expanding from the pole to the equator.

In 1983-1984 and again in 1992-1993, Voyagers 1 and 2 detected strong radio emissions bursts. A strong case can now be made that these bursts were triggered by the interaction of an interplanetary shock with one of the outer boundaries of the heliosphere. Voyagers 1 and 2, and Pioneer 10 are all monitoring anomalous cosmic ray fluxes that are particularly important to understand the structure of the heliosphere. Exploration of the heliosphere by these spacecraft, along with the Ulysses and the Earth-anchored IMP-8, constitutes the largest scale in-situ astrophysical investigation ever. It has taken more than two decades for the spacecraft to reach these positions. Pioneer 10 has traveled farther from the Sun than any other human artifact.

Nineteen years of IMP-8 mass flux data have been compared against solar neutrino fluxes. Results show that the solar wind mass flux and neutrino flux vary together, and may indicate the neutrino property's ability to interact with magnetic fields in the solar convection zone. IMP-8 continues to provide fundamental solar wind observations needed to improve the understanding and interpretation of the events observed within the magnetosphere by the GGS/ISTP spacecraft.

SAMPEX is a Small Explorer mission that uses the Earth's magnetic field as a giant magnet spectrometer to measure energetic electrons and ions from a polar orbit of about 500 km altitude. SAMPEX has been studying the increases in the Van Allen belt radiation, and the solar particle and cosmic radiation. SAMPEX is helping to find what causes these increases and to predict them. This data is important, in part because of radiation effects on spacecraft electronics, human spaceflight and the Earth's atmosphere, and also because the data reveals basic information about the Sun and the Universe. SAMPEX has found atoms from interstellar space in the Van Allen belts and the electrons from Jupiter over the Earth's poles, and many new facts about the solar wind and how the Sun interacts with the galaxy.

Yohkoh has revealed that the Sun appears 100 times dimmer at x-ray wavelengths today than in 1991. It has also discovered that the hottest parts of flares are frequently located at the top of high arch structures on the solar surface. Novel data analysis has been performed on YOHKOH images to revel solar dynamic effects not previously apparent.

FAST began operations late in 1996, and instruments are meeting design requirements. Burst mode measurements reveal the nature of electric fields, plasma processes, and acceleration mechanisms on time scales down to milliseconds.

**Mission Operations and Future plans**

The Space Science program continues to make progress in lowering MO&DA costs while preserving the science return from operating missions. The program is utilizing the savings, and seeking additional costs 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 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 1998 despite a significantly reduced MO&DA budget. In total, NASA expects to be funding 29 operational Space Science spacecraft at the end of FY 1998, compared to 18 at the beginning of FY 1995. Missions expected to begin operations before the end of FY 1998 include the Japanese VSOP (international SVLBI program, 1/97], Lunar Prospector (9/97), Cassini (10/97), ACE (12/97), TRACE (12/97), the European international Equator-S (late 1997), AXAF (8/98), and the Submillimeter Wave Astronomy Satellite (SWAS,TBD).

Occasionally, Space Science mission operations must be terminated, as a result of hardware failure and/or declining science output per dollar. The International Ultraviolet Explorer (IUE) ceased operations in September 1996 after more than 18 years of highly successful data gathering. The Pioneer mission series will be terminated on March 31, 1997 as the last spacecraft in the series, Pioneer 10, runs out of power. The European Infrared Space Observatory (ISO) is expected to cease operations in mid-1997 after it runs out of cryogens.

HST reached a milestone several years sooner than scientists expected when it snapped its 100,000th exposure on June 22, 1996. Space Telescope Science Institute officials largely attribute the achievement to better management of telescope observing time. This allows HST to put out more interesting scientific results to more astronomers and to the public.

Planning and hardware development in preparation for the next HST servicing mission in February 1997 continues on schedule. The manifest includes two new scientific instruments: the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) and the Space Telescope Imaging Spectrograph (STIS). In addition, one of the tape recorders will be replaced with a state-of-the-art Solid State Recorder (SSR). One of the Fine Guidance Sensors (FGS) is also manifested for replacement along with some electronics. Other servicing missions are planned for 1999, 2002 and 2005. Development of the Advanced Camera for Surveys (ACS), a new science instrument to be installed during the late 1999 servicing mission, continues on schedule.

The first major deliveries of AXAF ground hardware and software for integrated systems testing were completed early in CY 1996, as scheduled. The ground system will be sufficiently functional to support spacecraft testing in the summer of 1997. Full functionality is scheduled for December 1997, allowing the flight operations team to train for several months prior to launch of AXAF in August 1998.

NEAR launched from Cape Canaveral Air Force Station on a Delta II on February 17, 1996. It will flyby the asteroid Mathilde in June 1997 and shortly thereafter fire its propulsion system to adjust its orbital path. In January 1998, it will swing by the Earth to achieve the proper inclination to the elliptic plane to rendezvous with EROS. In January 1999, NEAR will come within 1000 km of EROS and fire its thrusters several times to orbit the asteroid. For the next year, it will take measurements of EROS at various orbit altitudes. Spacecraft operations will be completed in January 2000.

The Mars Global Surveyor (MGS) mission was launched from Cape Canaveral Air Force Station aboard a Delta II 7925 on November 7, 1996. After a 10-month cruise, ending in September 1997, MGS will use a combination of thruster firings and aerobraking for a period of four months to reach a nearly circular mapping orbit. Mapping operations are scheduled to begin in March 1998. MGS will maintain the low circular orbit for two years for the prime mapping portion of the mission. After this period, MGS will raise its orbit to the altitude required for planetary quarantine, and continue operations as a communications relay orbiter for other U.S. and international landed missions.

The Mars Pathfinder spacecraft was launched from Cape Canaveral Air Force Station in December 1996, and will reach Mars in July of 1997. The lander will be cushioned by large airbags, which will protect the tetrahedral lander, the microrover, and the scientific instruments. Once at rest on the planet's surface, the bags will deflate and retract, the lander will open like petals of a flower, and the spacecraft will transmit the entry, descent, and landing data, including a panoramic image of the landing site to the Earth. The rover will then roll off its petal, and begin engineering design tests, as well as compositional tests of the Mars soil. The nominal life of the mission is 7 days for the rover, and 30 days for the lander: however, both could last longer.

**BASIS OF FY 1998 FUNDING REQUIREMENT**

## SUPPORTING RESEARCH AND TECHNOLOGY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Space physics research and analysis | 31,100 | 35,900 | 41,600 |
| Astrophysics research and analysis | 31,700 | 36,600 | 35,400 |
| Planetary research and analysis | 93,400 | 94,300 | 130,500 |
| Mission Study and Technology Development | 26,700 | 24,400 | 28,600 |
| SIRTF ATD | 15,000 | 24,900 | -- |
| TIMED ATD | 15,000 | 1,800 | -- |
| Origins ATD | -- | -- | 25,000 |
| Exploration technology development | -- | -- | 20,000 |
| Information systems | 25,900 | 24,900 | 24,500 |
| High performance computing & communications | 600 | 3,200 | 5,600 |
| Total | 239,400 | 246,000 | 311,200 |

**PROGRAM GOALS**

The goals of the Supporting Research and Technology (SR&T) program in the Space Science Enterprise are to: (1) optimize the design of future missions through science definition, development of advanced instruments and concepts, and definition of proposed new missions: (2) strengthen the technological base for sensor and instrument development: (3) enhance the value of current space missions by carrying out ground-based observations and laboratory experiments; (4) conduct the basic research necessary to understand observed phenomena, and develop theories to explain observed phenomena and predict new ones: and, (5) continue the acquisition, analysis and evaluation of data from laboratories, airborne observatories, balloons, rocket and spacecraft activities. 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 United States scientific and technological expertise.

The goals of the Missions Studies and Technology Development program are to: (1) conduct conceptual studies of future missions and identify key mission-enabling technologies in the four science themes of Solar System Exploration, Structure and Evolution of the Universe, Sun-Earth Connection, and Astronomical Search for Origins and Planetary Systems: (2) develop mission-specific critical technologies that are needed to enable planned missions: and (3) conduct detailed definition studies and cost analysis of planned missions through Phase B in preparation for new start consideration.

The goal of the Origins ATD program is to develop and demonstrate the technologies needed to implement the Origins science missions which include Space Interferometer Mission (SIM), Next Generation Space Telescope (NGST), and Terrestrial Planet Finder (TPF). The technologies include the development of space-based lightweight, deployable telescopes and interferometers.

The goal of the Exploration Technology Development program is to develop and mature the technologies required for the remote exploration and investigation of planetary bodies, with a focus on Mars, Europa and comet/asteroid systems.

The Information Systems Program provides multidisciplinary science support in the areas of data management and archiving, networking, scientific computing, visualization, and applied information systems research and technology. Information systems and related technologies are essential to NASA's Scientific Enterprise.

The goal of the NASA High Performance Computing and Communications (HPCC) program is to 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. The goal of the Remote Exploration and Experimentation (REE) component of the program which is funded within the Office of Space Science is to develop low-power, fault-tolerant, high performance, scaleable computing technology for a new generation of microspacecraft.

**STRATEGY FOR ACHIEVING** GOALS

The SR&T program carries out its objectives by providing grants to universities, nonprofit and industrial research institutions, and funds to scientists and technologists at NASA 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. These grants help train future investigators in space science disciplines -- science and engineering graduate and post graduate students who will become the Nation's future scientific leaders. Many of these grants fund new types of detectors and scientific instruments which are flown aboard sounding rockets or balloons, and may later be adapted for flight aboard future free-flying spacecraft. These suborbital payloads, besides performing low-cost science and training future scientists, thus enable more capable, less costly future spacecraft, Other grants fund purely theoretical studies which help direct future experimental investigations.

Increasing emphasis is being made within NASA to better utilize advanced technologies in future missions. As a result, the Mission Studies and Advanced Technology Development (ATD) Program supports activities to develop new free-flying mission concepts and to ensure that the technology for a specific mission is mature before development begins in order to minimize cost, schedule, and technical risks. Mission concept and definition studies are also used to identify and define applicable new technologies and optimize their use within an affordable development cost.

The Exploration Technology Development program will achieve its goals by developing exploration technologies to respond to the mission needs defined by the space science community, while pro-actively creating new technology concepts to address exploration opportunities beyond the current series of defined missions. This effort is augmented by actively incorporating the robotics and surface utilization technologies initially developed by the Telerobotics and Mars Technology programs, and maturing them to flight readiness through a program of aggressive environmental tests, field trials, and full-scenario mission simulations.

The Information Systems program carries out its objectives by providing the science community reliable and efficient access to high performance computing, network services. and data resources. The program also provides an interactive analysis environment with efficient access to data, mathematical processing tools, and advanced visualization techniques. The science community, as the primary customer, is active in the planning, implementation, review, and evaluation of effectiveness of the program in meeting its needs. NASA is planning a unified Space Science Data System to integrate previously separate discipline data systems, to improve the data environment for interdisciplinary research, and to improve efficiencies in delivery of data services to the community. The information systems research and technology portion of the program is solicited through peer-reviewed NASA Research Announcements. Investigations at universities and research centers develop tools and techniques to improve scientists' productivity, as well as to provide transfer of new information technology into the private sector.

The REE project, led by the Jet Propulsion Laboratory, works in close partnership with the U.S. computer industry, academia, and other government agencies to enhance and enable the performance of spaceborne automated systems by providing computing technology which is dramatically reduced in power and mass, but increased in performance and reliability.

**MEASURES OF PERFORMANCE**

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| Complete SIRTF Phase A studies<br>Plan: September 1996<br>Actual: September 1996 | JPL in-house studies of alternative mission designs reviewed for relative technical merits (complexity, feasibility, etc.) cost and schedule requirements. |
| Complete SIRTF Spacecraft Request for Proposal (RFP)<br>Plan: September 1996<br>Actual: September 1996 | Documentation to support industry proposals for spacecraft development contract ready for release. Release contingent upon new start approval in FY 1997. |
| ESA Rosetta Conceptual Review for PI Instruments<br>Plan: Spring 1997 | The European Space Agency (ESA) review for the Rosetta comet rendezvous mission instruments. U.S. PI instruments are Plasmas, Ultraviolet and Microwave Spectrometers. |
| Begin observations with the Keck Observatory<br>Plan: September 1996<br>Actual: September 1996 | Keck observations will support the Astronomical Search for Origins and Planetary System (ASO) theme. ASO activities are to detect extra-solar planetary systems, to understand their formation and evolution and to characterize individual planets. Other Keck activities will be the discovery and characterization of faint, small bodies in our solar system. |

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| Develop self-replicating systems to model Earth's earliest life<br>Plan: September 1996<br>Actual: September 1996 | Ribonucleic Acid (RNA) catalytic capabilities can now be evolved in test tubes with manipulation. Work is aimed at developing an RNA capable of self-replication and mutation, as the first demonstration of life based solely on RNA. RNA can now be replicated and evolved through sequentially replacing highly-specialized media, analogous to the serial culture of bacteria. |
| Synthesize biologically important compounds from abiotic chemical processes operating in hydrothermal vents<br>Plan: September 1996<br>Actual: September 1996 | High pressure-temperature vessels have been built and the abiotic synthesis of organic compounds has been detected. Finding sufficient production of important biological compounds would support the theory that hydrothermal vents are a site for the origin of life on Earth. |
| Complete two-year program to analyze the data sets acquired of the Comet Shoemaker-Levy 9 collision with Jupiter<br>Plan: September 1996<br>Actual: September 1996 | The impacting fragments and subfragments of the original comet nucleus were found to be made of dust. Very little water or evidence for other ices has been detected. Limits on material properties of the nucleus have been determined from Jupiter's tidal disruption of the original comet nucleus. This information is being used to estimate strengths of nuclei in preparation for comet lander missions. Many features in the Jupiter atmosphere caused by the impacts are still being studied. |
| Technology development of advanced x- and gamma ray detectors<br>(ongoing) | Significant progress continued in FY 1996 in programs aimed at developing better sensors and optics to investigate cosmic radiation in the x- and gamma-ray bands. A major peer review was conducted, resulting in the selection of a number of innovative high energy detector and optics technologies. At x-ray wavelengths, several projects aimed at developing advanced detectors with ultra-high energy resolution, good spatial resolution, high quantum efficiency, and large format are being carried out. One such device was tested in a sounding rocket flight and demonstrated the best spectral resolution ever obtained by an x-ray detector operating in the space environment. In the gamma-ray band, detectors with advanced capabilities spanning the various energy bands from hard x-rays to very high energy gamma-rays are being developed. Work will ontinue on advanced optical systems, including very high resolution x-ray mirrors and grazing-incidence optics with response extending into the hard x-ray band. |
| Technology development of advanced infrared detectors<br>(ongoing) | Continued and significant progress was made in developing, characterizing and refining infrared detectors suitable for low-background applications in space astronomy. A primary motivation for developing a variety of detectors and associated electronics is the requirement to support NASA's next infrared missions for the coming decade, SIRTF and SOFIA. Moreover, during FY 1996 consideration began on development of the next generation of detectors and associated instrument electronics for the Next Generation Space Telescope (NGST). |

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| Technology development of advanced submillimeter detectors (ongoing) | Significant milestones continue to be met and surpassed in the continuing development of bolometer and heterodyne sub-millimeter detectors. The lightweight "spider-web" bolometer technology pioneered by Andrew Lange (CalTech) features a large effective area for detection, but a very small cross-section to cosmic ray hits. Harvey Moseley (NASA Goddard) demonstrated a technique for constructing for the first time arrays of sub-millimeter bolometers, which may be used to fill the focal plane of future astronomy observatories working at this wavelength. |
| Technology development of advanced Ultraviolet (U/V) detector systems (ongoing) | Ultraviolet detector development and work on associated instrumentation and electronics continues, in preparation for a number of approved and potential space astronomy missions, including the FUSE spacecraft and Advanced Camera for Surveys (ACS) for the HST. These and other programs will benefit from the successful development in delay-line microchannel plate detector electronics and anode fabrication. |
| Theoretical studies of solar physics (ongoing) | Lmportant progress continues to be made in understanding interactions of solar magnetic fields with the flow of ionized material that leads to the variability of the Sun. Models recently constructed for the interior of this star will soon be specific enough for observational testing. Also, in FY 1996,working from observed surface magnetic fields, theorists successfully predicted the form of outer corona structures seen weeks later during a total solar eclipse. Research continues in estimating the intensity of the solar activity maximum, expected during the next five years. |
| Instrumentation concepts tested on the closest star (ongoing) | Detector arrays of ultra-high spectral resolution germanium are demonstrating their promise for Fourier gamma-ray imaging of solar flares, a key tool for understanding the radiation from accelerated flare particles. At the same time, continuing effort in high angular resolution images and magnetic field measurements seek innovative ways to simplify and improve flight instrumentation. |
| Analyses of solar observations (ongoing) | The mechanisms of solar variability are being investigated and these solar causes are connected with their effects on the Earth environment and human systems. Studies of coronal mass ejections (CMEs) recently showed the need for "stereo" viewing of these disturbances from a position away from the Earth-Sun line in order to distinguish driven shocks versus blast shocks associated with CMEs. |
| Theoretical studies of Geospace (ongoing) | Analysis and modeling of the behavior of the Geospace system, especially as impacted by the light, magnetized plasma, and energetic particles produced by the Sun. |

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| Theoretical studies of the Heliosphere (ongoing) | Continued science definition, new technology development and instrument design for a close solar flyby mission to study how the corona is heated and the solar wind is accelerated. |
| Theoretical studies of Magnetospheres (ongoing) | The goals in the Magnetospheric Physics Program are to understand the nature of magnetospheres, including their formation and fundamental interactions with plasmas, fields, and atmospheres. The NASA program emphasizes research upon the Earth's magnetosphere, which results from the interaction between the solar wind plasma and the geomagnetic field, but also includes magnetospheric research on planets, comets, and other primordial bodies. |
| Investigations of magnetospheric structures and events coupled to solar and heliospheric processes (ongoing) | Research is conducted on the fundamental components of the Earth's magnetosphere. At its outer limits, these include the bow shock, the magnetosheath, the magnetopause, and the geomagnetic tail. Within the magnetosphere are the plasmasphere, the plasma sheet, the boundary layer plasmas, and other highly time-dependent plasma populations such as the radiation belts that relate to solar and heliospheric events. Two dramatic transient events are magnetic storms and substorms (roughly analogous to hurricanes and tornadoes, respectively, in the lower atmosphere) which occur subsequent to extreme conditions on the Sun or in the solar wind. |
| Mars Surface/Subsurface Exploration Technology (ongoing) | Identify and select most promising architectures for long-lived, highly mobile long-distance Mars surface exploration missions. Initiate program to address critical mobility and sampling technologies to support these approaches. |
| Europa Surface/Subsurface Exploration Technology (ongoing) | Develop autonomous drilling approach to enable robotic access to the subsurface environment of Europa. Define expected range of sub-ice operational and communications constraints and identify key technical approaches to enable this class of missions. |
| Comet/Asteroid Surface/Subsurface Exploration Technology (ongoing) | Define key sample acquisition and in-situ analysis capabilities needed to enable extended exploration and analysis of a low density/low gravity (comet or asteroid) surface. |
| Origins Advanced Technology Development (ongoing) | Develop and demonstrate the technologies for space-based interferometers and large lightweight telescopes. |

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| Investigate the loss of volatiles from Mars' atmosphere over geologic time, based on new atomic and molecular data and a new understanding of loss processes (ongoing) | Hydrogen, oxygen, nitrogen, carbon and other constituents are critical in the process of evolution of the Martian atmosphere and climate. This study is directly related to the question of whether the early atmosphere of Mars was denser, warmer and wetter, and therefore whether Mars could have been the abode of primitive life. |
| Investigate hydrocarbon ion production in Jupiter's auroral region due to charged particle impact, based on new atomic and molecular data (ongoing) | A continued investigation of hydrocarbon ion chemistry in the ionosphere of Jupiter. The work is important because hydrocarbon ion chemistry, driven by auroral particle impact, is probably a significant process in the production of the heavier hydrocarbon molecules that form Jupiter's polar haze. |
| Determination of the likelihood that a planet would be habitable (ongoing) | Research will focus on the necessary atmospheric ingredients for a liquid water world, how evolution of the planet's Sun alters the circumstellar "habitable distance" in which liquid water is maintained, and the probability of planets occurring within the habitable distance. Models of greenhouse gases have extended the possible habitable distance to farther from the Sun. |
| Determine how life started on Earth (ongoing) | Investigations will take two general approaches: 1) retrospective in deducing our earliest ancestors through phylogeny and the fossil record, and 2) through laboratory experiments to recreate the possible synthetic pathways leading to the origin and evolution of life. |
| Continue long-term astrometric and radial velocity searches for the presence of massive planets (ongoing) | During FY 1996, long-term observational programs finally revealed the unambiguous presence of faint Jupiter-mass objects in orbit around neighboring stars. These programs use either precise measurements of a star's position or minute changes in the star's velocity to infer the gravitational tug of an orbiting planet. To date, about a dozen such objects have been reported, revealing a new planetary system in space at the rate of about once per month. |
| Stratigraphic and structural analyses of geologic units on the terrestrial planets (ongoing) | Systematic geologic mapping of Venus and Mars is progressing at several scales. Significant stratigraphic and structural details have been derived from these studies, including newly described geologic sequences involving the relative timing of units identified on the planets. Ongoing analysis of spectral reflectance data for the Moon obtained by the Clementine mission is also improving compositional constraints on lunar geologic evolution. |

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| Detect and characterize individual interstellar grains in meteorites and IDPs (ongoing) | A variety of interstellar grains have been detected in meteorites and interplanetary dust particles that have been shown to have been formed in novae, supernovae and red giant stars. New microanalytic techniques allow investigators to characterize the chemical composition of individual grains and to better understand the conditions in particular stars during the synthesis of each individual grain. This provides significant insight into the problems of stellar nucleosynthesis and stellar evolution. |
| Use isotopic traces of extinct radionuclides to bound the timescales for the formation of planets (ongoing) | A variety of short-lived radioactive elements are known to have been present in the early solar nebula. By searching for the isotopically distinct daughter products of a number of these elements and comparing their abundances with stable, chemically similar elements, it is possible to bound the sequence of processing events that led to the formation of individual planetessimals and to develop an absolute chronology for the evolution of the planetary system. By mapping the abundances of the shortest-lived isotopes it is possible to bound the time of the last addition of material to the presolar molecular core as well as the timescale for the collapse itself. |
| Identify the changes to specific types of planetary materials caused by the space and planetary environments (ongoing) | A wide variety of meteorite types, including meteorites from the Moon and Mars, are available for laboratory analysis. A basic understanding of the effects of the space environment and weather of the planets on the spectral properties of the meteorite samples is needed before these properties can be linked to spacecraft remote sensing observations of planets. These samples simultaneously reveal a great deal of the evolutionary history of the parent body from which the meteorite sample was derived. |
| Search for additional millisecond pulsars and monitor the planetary system discovered around the neutron star PSR1257+12 (ongoing) | Observations using the Arecibo and Effelsburg radio telescopes are underway to find and catalog a large number of millisecond pulsars that can then be monitored for gravitational perturbations due to the presence of a planetary system. These telescopes are also being used to monitor the evolution of the planetary system around PSR1257+12, using mutual gravitational interactions to accurately determine the masses and orbital elements of the planetary system. |
| Studies of the chemistry and structure of star-forming interstellar clouds (ongoing) | One of the most active areas of astrophysical research is the investigation of the thermodynamics, chemistry, and structure of the material out of which new generations of stars are born. This involves not only observational programs across the entire electromagnetic spectrum, but also laboratory and theoretical programs which extend our general knowledge of basic chemistry. To date, around 100 different molecules have been discovered in the material between the stars. |

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| Continue development and validation of high priority planetary technologies (ongoing) | Solar Electric Propulsion needs to be validated for high energy missions: acquisition and analysis of samples from planetary surfaces and atmospheres must be developed for future in depth studies of the solar system; utilization of local resources is the key to long term self sufficiency of the exploration program. |

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Revised | plan |
| NSSDC accesses per day | 40,000 | 40,000 | 50,000 | 44,000 | 48,000 |
| World Wide Web Homepage visits per day | 30,000 | 18,000 | 40,000 | 30,000 | 40,000 |
| NSI Nodes | 240 | 240 | 240 | 240 | 240 |
| Principal Investigator Users | 2,300 | 2,200 | 2,300 | 2,200 | 2,200 |

**ACCOMPLISHMENTS AND PLANS**

NASA's R&A program continued to produce exciting scientific results in FY 1996. In 1996, evidence that life existed on Mars was reported by scientists based on their analysis of an ancient Martian meteorite, ALH84001, collected in Antarctica as part of an ongoing NASA/NSF/Smithsonian program. Over the past decade, the scientific community has come to realize that life outside of Earth is probable considering that: (1) life exists on Earth wherever there is liquid water; (2) life appeared very quickly on early Earth; and (3) early Mars had an environment similar to early Earth. In response to the exciting findings that galvanized scientific and public interest, NASA and NSF have initiated a special meteorite analysis program concerning Martian meteorites, specifically ALH84001. The goal is to confirm or refute the purported evidence of Martian life and to recognize the limits of knowledge of what may be learned from Mars meteorites.

Life is most probably a natural consequence of the physical and chemical processes in the universe. 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 will be initiated in 1997. The program will focus evolutionary biology research on the fundamental information about the evolution of life on Earth to anticipate the likelihood and nature of life elsewhere in the universe.

Balloon-borne programs offer scientifically compelling results at a fraction of the cost of satellite missions for some specific types of observations. For example, the R&A program supports balloon-based studies of the cosmic background emission at sensitivities which will exceed that of the historic Cosmic Background Explorer (COBE). Furthermore. observations at smaller angular scales will reveal characteristic structure of the cosmos which will significantly constrain the values of three major "cosmological constants," including the early rate of universal expansion and the mass density of the universe.

Significant progress continued in the development and testing of innovative new x- and gamma-ray detectors. A state-of-the-art x-ray calorimeter was flown on a sounding rocket from White Sands, N.M., and obtained the best spectral resolution (–9 eV) ever

obtained in the space environment. This flight represents the first space-based demonstration of this very powerful new technique and is extremely encouraging for the prospects for the successful operation of a similar instrument on the NASA/ISAS Astro-E mission, planned for launch in early 2000. Even during the 200-second observation afforded by this rocket flight, the x-ray detector was able for the first time to resolve spectral lines of Oxygen VII from the diffuse x-ray background radiation. With further improvements in energy resolution expected as a result of the flight, the diffuse Carbon blends seen at lower energies will also be resolvable. This data is providing important new information on the origin and composition of the very hot gas which fills the space between the stars in our galaxy.

Analysis of data from the flight of a high-resolution gamma-ray spectrometer flown from Australia in early FY 1996 revealed surprising new results on another component of the Milky Way's interstellar medium. The faint glow of the gamma radiation line indicative of the radioactive decay of 26 Al detected by the Compton GRO mission was observed and found to be some three times broader than expected from prevalent models. This result strongly suggests that such emission originates from gas ejected in supernova explosions and/or from the extremely energetic "winds" of material expelled from very hot and massive stars in the disk of the Galaxy. It has also raised a new question of how the material maintains such a high velocity over the million years or so since its production.

In the field of coherent detector development, various programs in universities, industry, and NASA centers are achieving three major goals: extending the performance to higher (> 1 Thz) frequencies, decreasing the noise level to approach a few times the quantum limit, and constructing arrays of detectors. Such systems will be essential to NASA's SOFIA observatory, ground-based submillimeter detectors in the U S . and elsewhere, and ESA's Far Infrared and Submillimeter Space Telescope (FIRST)mission.

During FY 1997-1998, the Sun-Earth Connections theme will observe and interpret the variable radiations in the Earth's space environment. The Sun, its atmosphere and heliosphere, and the Earth's magnetosphere and atmosphere are coupled by physical processes that are only partially known. These processes will be explored to achieve major advances in understanding. The theme focuses on the solar atmosphere and flares, global magnetospheric structure and dynamics, and upper atmospheric structure and energetics, as well as the coupling among them. Sun-Earth Connections examines the frontiers at both the very inner and outer fringes of our solar system, and plans to explore in-situ deep in the solar atmosphere, closer to the Sun than ever before.

In FY 1997, a second sounding rocket flight of an advanced x-ray microcalorimeter device is planned. The primary goals are to demonstrate an enhanced spectral resolution resulting from changes to the instrument design and to observe a galactic supernova remnant to investigate the supernova phenomenon. including the nature of the progenitor star, the explosion, and its interaction with the interstellar medium.

In FY 1998, the supporting research and technology program for the discipline of high energy astrophysics will continue to emphasize the development, fabrication, and flight-testing of space-qualified detectors with enhanced imaging and spectral capabilities in the x- and gamma-ray bands. In addition, innovative x-ray telescope developments will continue to be investigated, with efforts aimed both at very high spatial resolution and at high throughput together with moderate spatial resolution, as well as at the extension of focusing optics into the hard x-ray band.

The Suborbital Program in Magnetospheric, Ionospheric, Thermospheric, and Mesospheric (MITM) physics continues its critical support of MITM programs through its provision of fast, inexpensive access to space. Analysis of previously obtained aircraft-based data has, for instance, provided significant insight into the physical mechanisms underlying sprites and other newly-discovered thunderstorm-associated phenomena. Balloon-based studies of sprite electric fields, critical but currently unknown quantities, are being planned for the summer of 1998. Work is also beginning on a sounding rocket investigation which will provide, in the winter of 1998/1999, the first flight test of JPL's hockey-puck-sized Free Flying Magnetometers.

Planet-sized objects have been detected indirectly at the rate of about one per month since the first object was discovered in late 1995. The central stars of these putative planets are normal, similar to our own Sun, which suggests that planetary systems are common constituents of the Universe. However, at present these indirect techniques are sensitive only to the most massive orbiting objects, Jupiter's mass or larger. Furthermore, some of the newly-discovered objects are likely to turn out to be very small stars, rather than planets. Future missions and instruments will be able to search for less massive objects.

Comet Hale-Bopp continues to brighten and shows high jet-like activity. Its perihelion is April 1, 1997. The comet comes on the heels of Comet Hyakutake, which yielded several unanticipated results: x-ray emissions, and several molecules (acetylene and ethylene) detected for the first time in a comet. A joint NASA-NSF Comet Hale-Bopp Initiative has competitively selected 13 teams of investigators for funding for a period of two years. Special filters for observing the comets have been acquired and are being calibrated. Observing activities will reach their peak when the comet is near perihelion.

The Solar Electric Propulsion (SEP) technology development will complete the 8,000-hour life tests on the engineering model in FY 1997. Also in FY 1997, the flight SEP hardware will be delivered for integration into the New Millennium Program Deep Space I spacecraft. DS I will be launched in July 1998 and will demonstrate the first use of SEP for primary spacecraft propulsion in space. A three-year, ground-based mission profile test will be started in late FY 1997 and continue through FY 2000 using the engineering model hardware.

Three programs and associated ground-based observatories and instrumentation dedicated to detecting Near-Earth Objects (NEOs) have been established: Spacewatch at Kitt Peak, Lowell Observatory Near-Earth-Objects Search (LONEOS) at Flagstaff, and the Near-Earth Asteroid Telescope (NEAT) camera operated by JPL at the USAF installation on Maui. An upgraded version of the Spacewatch telescope and the LONEOS telescope will see first light in 1997. Expanded efforts for orbit determinations and cataloging will also start in 1997. The NEO survey is being coordinated with the Department of Defense and space agencies from other countries.

Phase A studies for SIRTF were completed and a project approval review conducted during FY 1996. Based upon that review, SIRTF was given permission by the Administrator in November of 1996 to enter Phase B studies. Also during November, an exact-scale model of one of the spectrographs to be flown on SIRTF by the IRS team was successfully operated on the 5-meter Hale telescope at Mt. Palomar. Spectra were obtained of targets ranging from the planet Saturn and its moon Titan to distant active galactic nuclei, and previously unseen spectral features were detected in many of these sources. The sensitivity of this spectrograph, when installed on SIRTF, is expected to be a full two orders of magnitude more sensitive than the Short Wavelength Spectrometer (SWS) now flying on the European Space Agency's (ESA's) Infrared Space Observatory (ISO). Two major contracts

were awarded during FY 1996: Lockheed Martin Missiles and Space was awarded responsibility for the spacecraft, as well as for mission integration, engineering, and launch; while Ball Aerospace and Technologies Corporation will be responsible for the cryogenic telescope assembly. *An* engineering model of SIRTF's mirror, with a new type of beryllium construction, is being tested under mission-like conditions of extreme cold: this design is expected to meet the mission requirements. Significant work on infrared detector systems is also being supported by the Astrophysics R&A program. The FY 1998 budget includes funding for Phase C/D under SIRTF Development: please refer to that section for a description of SIRTF's goals and plans for FY 1998.

Solar System Exploration ATD activities in FY 1997 and FY 1998 include continuing the definition studies of small advanced outer planetary probes, development of in-situ sample and return technologies for cometary missions, and advanced technologies and mission concepts for future Mars orbiters, landers, and sample return missions.

Sun-Earth connections ATD activities in FY 1997 and FY 1998 include continuing definition studies of missions emphasizing the use of small spacecraft and rapid development, including the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED), High Energy Solar Imager (HESI), Magnetospheric Imager (MI). and Solar Probe missions. The development costs for these four missions have also been reduced by a factor of four from the original concepts. IMAGE, a Midex version of MI, was selected for development in FY 1996 under the Explorer program. During FY 1996 nineteen new, innovative mission concepts were selected for study over a two-year period. Concepts and new technologies being studied include solar sails, 3-D imaging using 100 micro-satellites, light-weight deployable light concentrators, and multiple tethered satellites.

The Exploration Technology program will focus on the development of systems for the exploration of planetary bodies. Initially, the program will focus on three primary areas of interest: Mars, Europa and comet/asteroid systems. For the Mars thrust, the program will develop and mature technologies for the detailed examination of the Mars surface. Through the development of long-lived, highly mobile systems such as Mars atmospheric robotic balloons ("Aerobots") and aircraft, detailed exploration of Mars on a planetary scale will be enabled. In parallel, autonomous drilling and subsurface systems will be developed to enable the search for, and acquisition of, samples of deep aquifers that are theorized to exist at depths of 1-10 Km below the Mars surface. Related subsurface exploration systems will also be developed to permit the exploration of the subsurface seas that are believed to reside on Europa. Enabling technologies such as navigation autonomy, aqueous sample acquisition and autonomous analysis, robotic deep-shaft ice boring, and multi-transmission-medium communications technologies will be developed by the program to enable the ability for highly autonomous underwater robotic exploration. The third thrust, comet/asteroid exploration, will develop advanced technologies such as adaptive landing systems, low-power/low-temperature drilling and sampling systems, low-/no-gravity mobility concepts, and in-situ sample analysis capabilities to enable detailed exploration in very low gravity environments.

The Origins ATD Program will develop and demonstrate, on the ground and in space, technologies needed to'implemented a series of space missions. These space missions will answer such questions as: What are the origins of galaxies, how do stars and planetary systems form, and are there habitable planets orbiting nearby stars? The first two missions planned are Space Interferometery Mission (SIM) and the Next Generation Space Telescope (NGST). SIM would be the first world's first space-based interferometer, and would demonstrate many of the technologies that will enable future space-based interferometers, including the Terrestrial Planet Finder (TPF). NGST is currently planned to be a 4-8m IR optimized space telescope that will succeed the Hubble Space Telescope and will probe the very early universe to determine the origins of galaxies.

Two experiments to capture Interplanetary Dust Particles (IDPs)have been deployed on the Mir Space Station and are expected to return in spring 1997 for analysis. IDPs carry critical and unique information on processes in the early solar System and Interstellar Medium. the evolution of interstellar organics, and the origin of life.

The Keck Observatory became available to NASA scientists with the completion of the Keck II telescope in September 1996. The twin 10-meter telescopes of the Keck Observatory are the largest in the world, and will allow NASA astronomers to search for planetary systems around other stars with significantly greater sensitivity than has been possible with any other telescopes.

Throughout FY 1997, planning and hardware development will continue toward the goal of establishing an interferometry capability at the Keck Observatory. Ultimately, this will involve housing of equipment required to combine the two Keck 10-meter telescopes in addition to four one-meter outrigger telescopes.

The Exploration of Neighboring Planetary Systems (ExNPS) activity as part of NASA's Origins Program has been completed and the study team's final report was submitted in FY 1996. One of the first actions recommended for NASA in implementing the ExNPS plan is to issue a NASA Research Announcement (NRA) soliciting proposals for the first ExNPS dedicated non-interferometric instrument to be developed for the Keck II telescope. This NRA is currently in preparation with a target release date in January 1997.

As part of the Space Science Enterprise strategic planning process, mission and technology roadrnaps are being developed in each of the four science theme areas. These roadmaps, developed by the scientific community, were initiated in FY 1996 and will be completed in FY 1997. Mission definition studies and technology developments will start in FY 1998 for those missions that are incorporated into the OSS strategic plan.

Early in 1997, NASA will competitively select a group of participating scientists to augment the Mars Pathfinder mission science teams. These scientists will be supported to prepare models and data analysis tools in preparation for the Pathfinder landing in July 1997.

The Remote Exploration and Experimentation (REE) project is conducting short-term study contracts with industry and academia in FY 1996 to establish requirements, identify candidate designs and architectures and qualify potential methodologies. Beginning in FY 1997, REE will complete a detailed Project Implementation Plan with milestones and metrics, and will issue technology system development contracts to industry and academia.

Heliospheric supporting research includes studies of many new features of the interaction of the solar wind with the interstellar medium revealed by spectroscopy data from the HST, and by data from IMP-8, Voyager, Pioneer, Ulysses and SAMPEX. In FY 1996, scientists did new computer modeling of the ionization and acceleration of interstellar atoms and cosmic rays'which penetrate the solar system, the effect of this process on the magnetic field and plasma in the inner solar system, and the slowing of the solar wind at and near the termination shock. These studies will be updated as the Voyager Interstellar Mission approaches the termination shock.

Heliospheric studies of the inner solar system and the source of the solar wind continue to integrate new remote sensing from **SOHO** and other observatories with in-situ plasma measurements from Ulysses and other spacecraft, into the best understanding of how the Sun creates the solar wind and establishes its character. 1996 **SOHO** results showing that the solar wind is already quite fast just a few solar radii from the Sun are important for design of a solar probe mission to find the solar electromagnetic process which accelerates the solar wind.

Preliminary studies of six innovative instruments for a possible close solar flyby to determine how the Sun heats the corona and accelerates the solar wind were funded in FY 1996 after peer review of proposals received in response to an NRA issued for this special purpose.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SUBORBITAL PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Kuiper airborne observatory | 3,400 | -- | -- |
| Stratospheric observatory for infrared astronomy | 30,000 | 21,300 | 45,800 |
| Balloon program | 16,000 | 14,000 | 13,700 |
| Sounding rockets | 38,600 | 28,800 | 24,900 |
| Total | 88,000 | 64,100 | 84,400 |

### PROGRAM GOALS

The principal goal of the Suborbital program is to provide frequent, low-cost flight opportunities for space science researchers to fly payloads to conduct research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. The program also serves as a technology testbed for instruments which may ultimately fly aboard orbital spacecraft, thus reducing cost and technical risks associated with the development of future space science missions. It is also the primary program for training graduate students and young scientists in hands-on research techniques.

### STRATEGY FOR ACHIEVING GOALS

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. The Spartan program, funded within the Sounding Rocket budget element at a level of approximately $1.5 million per year, provides access to space by supporting deployable payloads for flight aboard the Shuttle. Activities are conducted on both a national and international cooperative basis.

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 Space Agency (DARA) integrated into a used 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, including regions of star and planet formation in the Milky Way, activity in the nucleus of the Milky Way, and planets, moons, asteroids and comets in our Solar System. The program will build upon a very successful program of flying teachers on the KAO by reaching out to K-12 teachers as well as science museums and planetaria around the country. Development of SOFIA will start in FY 1997, with initial operations by

October 2001. KAO operations were terminated in October 1995; the savings from cessation of KAO operations are an integral element of the funding plan for SOFIA.

The FY 1998 budget proposes appropriation language for multi-year funding for development of SOFIA. The requested appropriations are $45.8 million for FY 1998, $56.5 million for FY 1999, $48.8 million for FY 2000 and $32.4 million for FY 2001, for a total of $234.8 million, including prior funding for design and definition. Enactment of these appropriations will ensure the stability to manage and execute this program within its budget and schedule commitments.

The Balloon program provides 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 the Antarctic. The Balloon program is managed by the NASA/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 advanced long-duration program based on superpressure balloons.

Sounding rockets are uniquely suited for performing low-altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurora and the coupling of energy into the atmosphere: and the nature, characteristics and spectra of radiation of the Sun, stars and other celestial objects. In addition, the sounding rocket program allows several science disciplines to flight test instruments and experiments being developed for future flight missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. The program is managed by GSFC/WFF, and launch operations are conducted from facilities at WFF, White Sands, New Mexico and Poker Flats, Alaska, as well as occasional foreign locations.

In 1996 a suborbital restructuring study evaluated the current implementation approaches and their suitability for meeting the requirements, including an assessment of possible restructuring alternatives. The study team concluded that NASA should maintain the viability of its suborbital activities, which are an essential component of the spectrum of access-to-space opportunities. It suggested that the sounding rocket program should be restructured to a Government-Owned, Contractor-Operated (GOCO) implementation approach, with market forces allowed to influence the final decisions concerning the implementation strategy.

The balloon program is already implemented via a GOCO approach, whereas the sounding rocket program is operated by a NASA-Contractor Team approach. In the latter case, the government performs both the oversight and implementation functions, with

help from contractors. The restructuring team suggested that a GOCO implementation approach would be consistent with the Zero Base Review budget and staffing levels, while offering an appropriate government role in providing crucial oversight without competing with industry. It was emphasized, however, that NASA should take appropriate action to mitigate possible adverse impacts that the transition to the GOCO might have on the users, and have a plan to retreat if necessary.

In an effort to broaden the education opportunities using experiments built by students and flown on suborbital rockets and stratospheric balloons, a Student Launch Program has been established for U.S. institutions of higher learning. This program offers students for the bachelor through masters degree an opportunity to work on a reasonably complex project from its inception through its end, in a timeframe tenable within their academic careers. A NASA Research Announcement released in June 1996 offers proposers up to $35,000 over 30 months or less for the design, construction, and flight of student-built balloon and/or sounding rocket experiments, including analysis of data. The announcement emphasizes that this program is meant to be equally relevant to students in academic fields as diverse as, for example, science and engineering, education, business administration, industrial management, and public relations. The experiments are intended to support the students' education, not to perform an experiment at the frontier of science.

The Spartan program provides small, 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.

## MEASURES OF PERFORMANCE

### SOFIA Development

| | |
|---|---|
| RFP Released<br>Plan: February 1996<br>Actual: May 1996 | Request for Proposals from industry for the SOFIA development and operations prime contract. Delayed in order to incorporate a variety of modifications arising out of the draft RFP. |
| NASA/DARA MOU signed<br>Plan: April 1996<br>Actual: December 1996 | Formal agreement between NASA and the German Space Agency. Delayed by resolution of various minor wording issues: no substantive issues. |
| Prime contract award<br>Plan: August 1996<br>Actual: December 1996 | Selection of the SOFIA development and operations prime contractor. |
| System Requirements Review<br>Plan: April 1997 | Complete review of engineering technical requirements for the entire SOFIA system, with meetings in the U.S. and Germany. On schedule. |

| | |
|---|---|
| Telescope Assembly Conceptual Design Review<br>Plan: August 1997 | Formal review of the German contractor's concept for implementation of the telescope assembly. On schedule. |
| System Preliminary Design Review<br>Plan: April1998 | Review of the U.S. contractor's concept for development and integration of the observatory. On schedule. |

**Balloon Program**

| | |
|---|---|
| FY 1996 | 25 flights (versus 30 planned) were flown from four remote sites: Canada, Alaska, Antarctica, and Fort Sumner, NM. |
| FY 1997 | 28 flights are planned from Palestine, Texas, Fort Sumner, Canada, Alaska, and Brazil. |
| FY 1998 | Approximately 25 nights are planned. |

**Sounding Rockets**

| | |
|---|---|
| FY 1996 | 22 flights (versus 32 planned) were launched from four sites: Wallops Flight Facility (WFF), White Sands Missile Range (WSMR), Australia, and Alaska. |
| FY 1997 | 26 flights are planned from four sites: WFF, WSMR, Alaska, and Norway. Three flights will focus on the Hale-Bopp Comet. |
| FY 1998 | A minimum of 14 flights are planned, including 10 from Puerto Rico, 3 from Norway, and one from WSMR. |

**Spartan**

| | |
|---|---|
| FY 1996 | Spartan 201-3 mission conducted investigations of solar wind as correlative data measurements to support SOHO. Spartan 207 successfully deployed the Space Access and Technology inflatable antenna. Spartan 206 accommodated four space technology experiments: two successfully and two with partial success. |
| FY 1997 | Preparing for the fourth flight of the Spartan 201 solar telescope. |
| FY 1998 | Spartan 201-4 planned for launch and retrieval on STS-87 in October 1998 |

## ACCOMPLISHMENTS AND PLANS

In May 1996, NASA released the final RFP for SOFIA development and operations. 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 be operated for at least 20 years. The contract will be managed by NASA's Ames Research Center, Mountain View, CA. Other team members include Raytheon E-Systems - Waco, TX (formerly CTAS); 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 calls 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, test and deliver the flying astronomical observatory to NASA, and provide mission and operations support in approximately five-year increments. USRA's proposal calls for operating the aircraft out of Moffett Federal Airfield, Mountain View, CA. It is anticipated that the 747 SP aircraft will be purchased in early 1997 and modifications to the vehicle will begin in mid-1998. The telescope will be integrated and tested by late in the year 2000, with science flights scheduled to begin in 2001. The international Memorandum of Understanding between NASA and DARA was also signed in December 1996. The contractors on both sides of the Atlantic will initiate final design work, heading toward Preliminary Design Reviews in March and April 1998 for the telescope assembly and the overall system, respectively.

In FY 1996, 22 sounding rockets and 16 balloons were flown. Of particular interest was completion of the highly successful sounding rocket campaign in Australia in which 6 rockets were flown. Recent developments in long-duration ballooning now make it possible to accommodate 1-2 ton payloads for periods of up to 3 weeks. This capability provides an alternative to Spacelab missions for some investigators, and is now being used in polar campaigns for solar investigations and to fly cosmic ray experiments, Technology development for superpressure ballooning has been initiated. Funding in FY 1997 and FY 1998 will support the planned balloon and sounding rocket flights.

In FY 1996 two Spartan missions launched from the Shuttle supported the activities of the Office of Space Access and Technology (OSAT). These included the OSAT-Flyer and Inflatable Antenna experiments. Plans for FY 1997 and FY 1998 include the flight of Spartan 201-4, which will study the solar corona in support of the SOHO mission.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### LAUNCH SERVICES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Launch Services ..... | 245,300 | 240,600 | 236,300 |

### PROGRAM GOALS

To provide successful, on-time launch services for the Space Science missions at the least possible cost. Launch Services are a vital element in the achievement of the overall goals of the Space Science program.

### STRATEGY FOR ACHIEVING GOALS

Payloads may be launched aboard a number of vehicles, each of which supports a discrete performance class. Small payloads are launched aboard the Pegasus XL, which is provided by the Orbital Sciences Corporation (OSC) and requires in-flight deployment from a Lockheed L1011 aircraft. The Pegasus XL is capable of delivering payloads up to approximately 1,000 pounds to low Earth orbit. The Ultra-lite launch services budget supports the Student Explorer Demonstration Initiative (STEDI) which is managed by the Universities Space Research Association (USRA) in cooperation with NASA. Funding supports the development of three small university-developed spacecraft and the procurement of launch services. A contract for Ultra-lite launch services was signed with OSC in December 1994 to support the STEDI program. This new class of ELV will provide approximately one half the lift capacity of a Pegasus.

Medium class payloads require launch services capable of delivering up to 11,000 pounds to low Earth orbit. These missions are launched aboard the Delta launch vehicle, which is provided by McDonnell-Douglas (MDAC). These vehicles may be launched either from the Cape Canaveral Air Force Station (CCAFS) or, if a polar orbit is required, from the Vandenberg Air Force Base (VAFB). The Med-Lite is a new class of launch services which is capable of delivering payloads up to 5,000 lbs to low-Earth orbit. The Med-Lite contract was signed with McDonnel Douglas in February 1996 and offers launches on lower performance Delta and Taurus (to be provided by Orbital Science Corporation) launch vehicles.

Large class payloads requiring the delivery of up to 39,000 pounds to low-Earth orbit are launched aboard the USAF -managed Titan IV/Centaur launch vehicle. NASA is procuring the Titan IV/Centaur launch vehicle for Cassini via an existing contract between the United States Air Force (USAF) and Locheed-Martin Corporation (LM). A separate contract for mission unique integration activities is established directly between NASA and LM.

Payloads launched aboard the Shuttle may be delivered to a higher orbit via the use of an upper stage. The AXAF mission will be launched aboard the Shuttle, and will use an Inertial Upper Stage (IUS) manufactured by Boeing to deliver the spacecraft to a highly elliptical orbit.

## MEASURES OF PERFORMANCE

### Ultra-Lite Class Launch Vehicles

| | |
|---|---|
| SNOE launch<br>Plan: May 1997 | Launch aboard a Pegasus launch vehicle. On schedule. |
| TERRIER launch<br>Plan: August 1997 | Launch aboard a Pegasus launch vehicle. On schedule. |
| CATSAT launch<br>Plan: 3rd Qtr FY 1998 | Launch aboard a Pegasus launch vehicle. On schedule. |

### Small Class Launch Vehicles

| | |
|---|---|
| FAST launch vehicle.<br>Plan: TBD<br>Actual: August 1996 | Launch successfully from VAFB board the Pegasus XL/L1011 on August 21, 1996. |
| SAC-B/HETE launch<br>Plan: November 1996<br>Actual: November 1996 | Dual payload launch from WFF aboard Pegasus XL/L1011 launch vehicle on November 14. 1996. The Pegasus vehicle failed to separate the two payloads from the third stage. Spacecraft are not functional. |
| SWAS launch<br>Plan: TBD | Exact date of this launch is dependent upon successful return to flight of the redesigned Pegasus XL launch vehicle. |
| TRACE launch<br>Plan: October 1997 | Exact date of this launch is dependent upon successful return to flight of the redesigned Pegasus XL launch vehicle. |
| WIRE launch<br>Plan: August 1998 | Exact date of this launch is dependent upon successful return to flight of the redesigned Pegasus XL launch vehicle. |

**Med-Lite Class Launch Vehicles**

| | |
|---|---|
| Deep Space I launch<br>Plan: July 1998 | On schedule for launch aboard a Delta 7326 launch vehicle. |
| FUSE launch<br>Plan: October 1998 | On schedule for launch aboard a Delta 7320 launch vehicle. |

**Medium Class Launch Vehicles**

| | |
|---|---|
| NEAR launch<br>Plan: February 1996<br>Actual: February 1996 | Launched successfully February 17, 1996, aboard a Delta II launch vehicle. |
| Polar launch<br>Plan: February 1996<br>Actual: February 1996 | Launched successfully aboard a Delta II from Vandenberg Air Force Base (VAFB). Launch was initially delayed from mid-1994 to December 1995 due to technical problems with spacecraft. A subsequent delay from December 1995 to February 1996 was due to launch manifest conflicts. |
| Mars Global Surveyor launch<br>Plan: November 1996<br>Actual: November 1996 | Launched successfully aboard a Delta II launch vehicle on November 7, 1996. |
| Mars Pathfinder launch<br>Plan: December 1996<br>Actual: December 1996 | Launched successfully aboard a Delta II launch vehicle on December 4, 1996. |
| ACE launch<br>Plan: September 1997 | On schedule for launch aboard a Delta-II, D7925. |

**All Other Classes of Launch Vehicles:**

| | |
|---|---|
| Cassini launch<br>Plan: October 1997 | Launch aboard a Titan IV/Centaur launch vehicle. On schedule. |
| AXAF-I launch<br>Plan: August 1998 | On schedule for launch aboard STS, with an Inertial Upper Stage. |

## ACCOMPLISHMENTS AND PLANS

During FY 1996 five Space Science missions were launched successfully.

- The SOHO mission launched aboard an Atlas IIAS on December 02, 1995.
- The XTE mission launched aboard a Delta II on December 30, 1995.
- The Polar mission launched aboard a Delta II launch vehicle on February 24, 1996.
- The NEAR mission launched aboard a Delta II launch vehicle on February 17, 1996.
- The FAST mission launched aboard a Pegasus XL launch vehicle on August 21, 1996.

As of December 1996, three FY 1997 Space Science missions have already been launched. Another four missions are scheduled for launch in FY 1997. The missions that have launched are:

- The SAC-B/HETE mission was not successfully launched aboard a Pegasus XL on November 11, 1996. NASA has an independent team to investigate the causes of the failure and provide a corrective action plan.
- The Mars Global Surveyor launched successfully aboard a Delta-II launch vehicle on November 7, 1996.
- The Mars Pathfinder launched successfully aboard a Delta-II launch vehicle on December 4, 1996.

FY 1997-1998 launch services funding will support the following future launches:

- Small Explorer missions on small launch vehicles: SWAS (TBD), TRACE (10/97), WIRE (8/98), and SMEX-6 (6/00);
- Med-Lite launch vehicles: New Millennium Deep Space I (7/98), FUSE Explorer (10/98), IMAGE (11/99) and MAP (11/00) Medium Class Explorers (MidEx), Stardust (2/99), TIMED (1/00) and Discovery-5 (1st Qtr. FY 01);
- Delta-II launch vehicles: ACE Explorer (9/97), Mars '98 Orbiter (12/98) and Lander (1/99), and Gravity Probe B (GP-B) (10/00)
- Ultra-light launch vehicles: SNOE (5/97), TERRIER (8/97) and CATSAT (3rd Qtr. FY 98) Student Explorer Demonstration Initiative (STEDI) missions, and two University Explorer Class (UNEX) missions (1st Qtr. FY 00, 1st Qtr. FY 01).

Funds are also provided for a Titan IV/Centaur launch vehicle for Cassini in support of a planned launch in October 1997. The majority of these funds in FY 1996-97 are required for launch vehicle hardware from Lockheed Martin Corporation (LM) which is being procured for NASA by the United States Air Force (USAF). Funds also support mission integration activities at LM which are funded under a contract directly between NASA and LM.

In addition, FY 1997 and FY 1998 funding supports procurement of an Inertial Upper Stage (IUS) for the AXAF mission that will be launched aboard the Shuttle in August 1998. Mission integration requirements for Space Science launch services are also included in the budget profiles.

Launch of the Lunar Prospector (9/97) is being procured as part of the development contract with Lockheed Martin Corporation, and is funded in the Discovery budget element, not in the Launch Services budget. Lunar Prospector is planned for launch on a Lockheed Launch Vehicle-II in September 1997.

Life and Microgravity
Sciences and
Applications

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 1998 ESTIMATES

BUDGET SUMMARY

OFFICE OF LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS

SUMMARY OF RESOURCE REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Life sciences | | | | |
| Research and analysis | 55,200 | 58,000 | 50,000 | SAT2-6 |
| [Construction of facilities] | | | [2,000] | |
| Flight program | 54,400 | 39,400 | 35,500 | SAT 2-14 |
| Subtotal | 109,600 | 97,400 | 85,500 | |
| Microgravity science research | | | | |
| Research and analysis | 30,200 | 31,900 | 36,500 | SAT 2-19 |
| Flight program | 76,300 | 73,400 | 64,900 | SAT 2-26 |
| Subtotal | 106,500 | 105,300 | 101,400 | |
| Space product development | 26,500 | 13,000 | 12,900 | SAT 2-33 |
| Space shuttle/spacelab payload mission Management and Integration | 53,600 | 24,200 | 6,900 | SAT2-39 |
| Aerospace medicine/occupational health | 8,000 | 3,800 | 7,500 | SAT2-43 |
| Total | 304,200 | 243,700 | 214,200 | |

## SCIENCE. AERONAUTICS AND TECHNOLOGY

## FY 1998 ESTIMATES

## BUDGET SUMMARY

| Distribution of Program Amount bv Installation | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Johnson Space Center | 72,900 | 38,100 | 37.700 |
| Kennedy Space Center | 11.200 | 7.200 | 6.400 |
| Marshall Space Flight Center | 67.300 | 49.000 | 45.800 |
| Ames Research Center | 28.900 | 26.300 | 21.500 |
| Langley Research Center | 4.100 | 2,700 | 2.400 |
| Lewis Research Center | 53.300 | 41.000 | 37.700 |
| Goddard Space Flight Center | 1.300 | 22.200 | 27.800 |
| Jet Propulsion Laboratory | 13.600 | 16,700 | 13.800 |
| Headquarters | 51,600 | 40,500 | 21.100 |
| Total | 304.200 | 243.700 | 214,200 |

## :E OF LIFE AND MICROGRAVITY SCIENCE AND ATIONS

### PROGRAM GOALS

The NASA Life and Microgravity Sciences and Applications (LMSA) program leads the nation's efforts in space biological, physical and chemical research and aerospace medicine, supporting technology development, and applications using the attributes of the space environment to advance knowledge, to improve the quality of life on Earth, and to strengthen the foundations for continuing the exploration and development of space. LMSA activities are supportive of, and closely aligned to, the goals of the Human Exploration and Development of Space (HEDS) Enterprise. Those goals include: 1) increase human knowledge of Nature's processes using the space environment: 2) explore and settle the Solar System: 3) achieve routine space travel: and 4) enrich life on Earth through people living and working in Space.

Current performance measures for LMSA include number of principal investigators supported, number of research proposals received and number of major journal publications. After extensive internal discussions. and with significant input from the NASA Advisory Council, LMSA has identified the following major categories of metrics from which will be developed more specific metrics, data and tracking methods. Future metrics will include the number of peer-reviewed flight investigations completed successfully in proportion to those planned for completion, results from ground-based research grants published in peer-reviewed journals, technolagies to improve self-sufficiency of life support systems, and the percent of countermeasures developed versus those which are accepted for operational use.

The LMSA program has adopted the Lead Center management approach and is rapidly moving to implement the Lead Center concept through five major programs. The Johnson Space Center (JSC) will become the Lead Center for two programs: Advanced Human Support Technologies Program and the Biomedical Research Program. The Ames Research Center (ARC) will be the Lead Center for the Gravitational Biology Program. The Marshall Space Flight Center (MSFC) will take Lead Center responsibility for two programs: Microgravity Research and Space Product Development. Johnson Space Center has also been designated the Lead Center for all Space Station activities and is responsible for the cost, schedule and technical performance of the total program, including the LMSA portions of the overall program.

The science components of the Space Station program -- the NASA-Mir Research Program, and Space Station Facilities and Utilization -- are now under the management of the International Space Station program. The funding and budget justification for these activities is now included under the International Space Station (ISS) budget justification.

The Research and Analysis activities within the LMSA program support ground-based research and definition studies upon which fight experiments are based. The flight programs in LMSA develop experiments to fly on suborbital rockets, parabolic aircraft, and

orbiting spacecraft such as the Space Shuttle, the Mir Space Station and the International Space Station (ISS). Strategic direction, budget development, and advocacy. liaison and outreach for all of these experiments, as well as for additional attached Space Shuttle payloads developed by other NASA organizations, is conducted through NASA Headquarters. LMSA also develops the research requirements for the Space Station Research Program. LMSA is also responsible for maintaining the health and productivity of astronauts and developing requirements for medical operations and research.

The Life Sciences Research and Analysis program supports ground-based research and definition studies in six major areas; (1) Space Physiology and Countermeasures, (2) Space Human Factors Engineering, (3) Environmental Health, (4) Space Radiation Health, (5) Advanced Life Support, and (6) Space Biology. The Research and Analysis program also includes data archiving, laboratories, NASA Specialized Centers of Research and Training (NSCORTs), and joint activities with the National Institutes of Health (NIH) and the National Science Foundation (NSF). Ground-based research relies on such unique gravitational simulation facilities such as centrifuges.

The Life Sciences Flight program, consists of the Flight Experiments Program, the NASA/Mir Research Program (NMRP), the Space Station Science Utilization Program and other international cooperative efforts. The flight experiments program selects, defines, develops and conducts in-space medical and biological research, and tests advanced life support and extravehicular technologies. It works closely with the scientific community to develop a broad variety of multi-user research facilities designed to support the life sciences community's needs of the future.

The Microgravity Research and Analysis program supports ground-based research and definition studies for flight experiment candidates in five primary areas: (1) Biotechnology, (2) Combustion Science, (3) Fluid Physics and Transport Phenomena, 4) Fundamental Physics, and 5) Materials Science. Ground-based research facilities include laboratories, drop-tubes, and drop towers.

The Microgravity Flight program, consisting of the Flight Experiments Program, the NASA/Mir Research Program (NMRP) and the Space Station Science Utilization Program, provides a wide range of experimental capabilities. The flight program supports a broad variety of hardware experiments including both unique scientific experiments as well as multi-user research facilities. These fight experiments will serve as the cornerstone of microgravity and applications research in the future. Experiments are principally flown utilizing sounding rockets, parabolic aircraft, the Space Shuttle, the Mir Space Station, and/or other commercially-developed spacecraft.

The Space Shuttle/Spacelab Mission Management and Integration program performs the mission planning, integration and execution of all NASA/Spacelab, the NASA-Mir Research Program (NMW) and attached Space Shuttle payloads. The program integrates the scientific payloads into the various carriers, trains payload specialists, and performs system management and engineering development of flight equipment and software.

The Aerospace Medicine and Occupational Health program is responsible for development of policies and requirements to maintain and provide medical support to optimize the health, safety and productivity of our astronauts in space, and to protect and promote

the health and safety of all NASA employees. The program also develops technologies and applications including telemedicine and global health applications.

The Space Product Development program is now reflected in the LMSA program amounts. This program's budget was previously justified under the Space Access & Technology program. The Space Product Development program facilitates the use of space for commercial products and services through the creation of Commercial Space Centers and industry partnerships that provide expertise and access to NASA experiment facilities as well as access to space.

A review of the financial status of the LMSA program at the end of FY 1996 revealed that significant unobligated and uncosted balances existed within the program. These balances were found to have been built up over the last few years, and resulted for a variety of reasons. The existence of these balances has allowed the program to transfer FY 1996 and FY 1997 funding to Space Station development activities, as detailed in the revisions to these respective operating plans and the "FY 1997 Changes" section of this budget justification, as well as refocus some baseline research activities as described in the following budget justification. We expect these balances to be within agency thresholds, now under development, for this type of research program by the end of FY 1997.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### LIFE SCIENCES RESEARCH AND ANALYSIS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Life sciences research and analysis | 55,200 | 58,000 | 50,000 |
| [Construction of facilities] | | | [2,000] |

## PROGRAM GOALS

The Life Sciences Research and Analysis (R&A) program sponsors basic and applied research in biomedicine, biology, environmental science, and related technologies in support of the Agency's strategic goals. The program goals are: 1) to effectively utilize gravity, microgravity and other characteristics of the space environment to enhance our understanding of fundamental biological processes: 2) to develop the scientific and technological foundations for a safe, productive human presence in space for extended periods of time: and 3) to apply this knowledge and technology to improve our Nation's competitiveness, education, and the quality of life on Earth.

The Life Sciences Research and Analysis program supports applied research as well as basic research. Its basic research activities use the unique weightless environment of space as a tool to learn about basic structures and functions of humans, other animals, and plants. Its applied research activities enable the development of procedures or countermeasures to prevent the undesirable effects of space flight on humans. Life Sciences Research and Analysis pursues its goals through ground-based research programs and projects at universities, NASA Centers, nonprofit and industrial organizations, and other Federal agencies. It also finances specialized support facilities and technologies in support of the science community.

The Life Sciences Research and Analysis budget supports ground-based research in the following three programs: (1) biomedical research and countermeasures; (2) gravitational biology; and (3) advanced human support technology. The biomedical research and countermeasures program includes physiology, environmental health, radiation health, and behavior and performance. The gravitational biology program includes cell and molecular biology, developmental biology, and comparative and plant biology. The advanced human support technology program consists of advanced life support, advanced extravehicular activity systems, advanced environmental monitoring and controls, human factors engineering, and radiation shielding.

Research and Analysis also sponsors additional specialized activities and services. Its advanced technology development activities respond to the defined needs of the space life sciences ground-based and flight programs. The life sciences education and outreach activity informs the professional community about space life sciences findings and activities, encourages students of all ages to consider careers in space life sciences, and sponsors development programs aimed at those already engaged in life sciences research careers.

All Research and Analysis investigations that the Life Sciences Division sponsors are peer-reviewed. The program's research solicitations and peer review program are administered from Headquarters, and proposals submitted by NASA Field Center researchers are subjected to the same rigorous competitive standards as those of extramural researchers. Life Sciences' policies permit peer reviews of selected proposals to be performed under cooperative arrangements with the NIH.

## STRATEGY FOR ACHIEVING GOALS

The Life Sciences research and analysis program biomedical research and countermeasures research that 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, that optimize crew safety, well-being, and performance, and that minimize the deleterious effects of returning to Earth's gravity after spaceflight. It attempts to specify, measure, and control spacecraft environments, and it develops standards and countermeasures, where necessary, to optimize crew health, safety, and productivity. The program develops monitoring techniques, procedures, and standards for extended missions. It also seeks to establish the scientific basis for protecting humans engaged in the development and exploration of space from radiation hazards.

The program also seeks to 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 program emphasizes research in cell and molecular biology, developmental biology, and comparative and plant biology. Its research includes plants, animals, or other organisms as subjects, as well as cell or tissue cultures.

Additionally, the research and analysis program 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 support long-term human missions in space in a safe and reliable manner while minimizing the need for resupply. Its projects and activities apply engineering sciences to the design of technologies that support and control physical-chemical and bioregenerative closed loop systems for clean air and potable water. The program applies knowledge from the life sciences to develop technologies for growing, harvesting, and processing crop plants for flight crew consumption. The advanced extravehicular activity (EVA) systems program develops new technologies necessary to perform EVAs productively, safely, and efficiently during future long-duration missions, EVA systems are defined as the operational hardware and operational procedures that allow safe, efficient, and productive crew activities in the proximity of a planetary habitat, a spacecraft, or an orbiting station. EVA hardware includes space suits, portable life support systems, and items such as foot restraints, tools, work stations, and interfaces. These items, along with operational procedures and protocols, are candidates for advanced EVA systems technology development.

Space human factors pursues multiple objectives. It works to expand knowledge of human psychological and physical capabilities and limitations in space. It develops technologies that integrate the human and system elements of space flight. It encourages mission planners to use human factors research results and technology developments to improve mission results and crew safety. The program makes NASA technologies available to the private sector for Earth applications.

The Advanced Technology Development (ATD) project sponsors multidisciplinary technology development activities that enhance the capability, reliability and quality of Life Sciences flight hardware. The program solves technical problems that currently limit science return from existing flight equipment. It enables new types of scientific investigations in space; promotes technology transfer of Life Sciences technology to industry; and establishes partnerships with industry, universities, and other agencies.

**Center Support**

The Life Sciences Research and Analysis (R&A) program currently manages its projects, activities, and tasks from Headquarters and the Ames Research Center (ARC), the Johnson Space Center (JSC), and the Kennedy Space Center (KSC). The program is actively working to implement the Lead Center program management approach and will be formally assigning lead center responsibility to both JSC and ARC. JSC will be the lead center for the Biomedical Research Program and the Advanced Human Support Technologies Program. ARC will be assigned responsibility for the Gravitational Biology Program. The R & A program also draws upon other Centers on occasion to administer tasks or for other unique expertise. Following the program's adoption of revised peer review procedures during FY 1994, the Life Sciences program returned the responsibility for grants peer review and selection for funding to Headquarters. As a result, all proposals selected for funding, both those submitted by extramural investigators as well as those from intramural researchers at NASA Centers, must withstand a Headquarters-managed, competitive selection process. Effective in FY 1997, grant awards made to extramural investigators are being administered by the Goddard Space Flight Center (GSFC), which is now providing grants administration support to Headquarters science programs.

**NIH Cooperation**

Within Life Sciences, $10.0 million each year supports collaborative activities with the NIH, of which more than $5.0 million is supported under the Research and Analysis program. NASA/Life Sciences resources dedicated to joint NASA/NIH collaboration are likely to increase in future years, stimulated both by the success of past collaborative efforts and by the recommendations of the NASA/NIH Interagency Advisory Committee. A key collaborative venture between NASA and NIH is the Human Brain project, an activity which concentrates on neural science and informatics research. NASA and NIH will continue to provide mutual support to a NASA/NIH Specialized Center of Research and Technology (NSCORT) for Vestibular Research at Northwestern Medical Center in Chicago. A sampling of other collaborative research and technology projects that NASA Life Sciences has underway with NIH include several projects in cancer research, including a technology development task which aims to develop advanced digital mammography techniques. NASA and the National Cancer Institute (NCI) are jointly supporting radiation biology research into the fundamental processes leading to cancer. This research will provide benefits for extended space flight and occupational health. NASA and NIH are working together on neurological and behavioral sciences research, developmental physiology and human development research, cardiovascular, pulmonary, and hematologic systems research, and the application of remote sensing satellites to predict and control human disease. The two agencies are supporting several activities designed to enhance the electronic information services available to life sciences researchers. For example, SPACELINE, an on-line bibliographic database of space life sciences developed in collaboration with the National Library of Medicine (NLM), recently became available for use.

## Other Collaborative Activities

The objective of establishing a strong radiobiology program at Loma Linda University Medical Center began during FY 1996 and will continue during FY 1997. Congressional action provided $4.5 million of FY 1996 resources for this purpose, and follow-on Congressional action has designated the application of an additional $4.0 million from FY 1997 appropriations. During FY 1996, Life Sciences initiated a cooperative agreement with the Loma Linda University that will support up to 400 hours of proton beam time and core support for proton research at Loma Linda University. The University is constructing a building containing laboratory space dedicated to the radiobiology program. In FY 1997, LMSA plans to initiate a cooperative effort with the Cleveland Clinic in cardiac imagery activities. Definition of this activity is underway.

Life Sciences also participates with other Federal agencies such as the Department of Energy (DOE), the Department of Defense (DOD) and a variety of other national and international organizations whose research interests intersect those of the Research and Analysis program. These organizations include the National Science Foundation, the American Society for Gravitational and Space Biology (ASGSB), the Aerospace Medical Association (AMA), and the American College of Sports Medicine (ACSM). The program also reaches out to groups whose members are underrepresented in the life sciences research community, such as the Alaska Native Association (ANA).

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Revised | plan |
| Number of Ground Principal Investigators | 224 | 210 | 232 | 200 | 200 |
| Number of Co-Investigators supported (Ground-Based and Flight) | 291 | 300 | 302 | 290 | 290 |
| Number of Refereed Publications (Ground-Based and Flight) | 540 | 540 | 600 | 525 | 525 |

Release Life Sciences NASA Research Announcements — Ensure a steady source of peer-reviewed research and development tasks.

Plan: 1st Qtr FY 1996
Actual: 2nd Qtr FY 1996

Plan: 1st Qtr FY 1997
Revised: 2nd Qtr FY 1997

Plan: 2nd Qtr FY 1998

| | |
|---|---|
| Initiate 5-year performance period for new NSCORTS.<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996<br><br>Plan: 3rd Qtr FY 1997 | New NSCORTS in Gravitational Biology and Bioregenerative Life Support were selected in FY 1996. New Radiation Health NSCORT due for selection during third quarter FY 1997. |

**ACCOMPLISHMENTS AND PLANS**

The Research and Analysis program is taking steps to improve the quality of its research selections and to increase the budgetary resources that it makes available to research investigators. Forty-seven research proposals selected in FY 1996 received multi-year research awards valued at approximately $15 million through FY 1998. The NASA/Life Sciences hopes to award a comparable number during FY 1997 and during FY 1998. All awards will derive from proposals submitted in response to the NASA's competitive selection and peer review procedures. Additionally, the FY 1997 and FY 1998 program activities will include increased activity in areas of collaboration with other federal agencies and non-federal organizations, notably in the area of radiation health. A number of Life Sciences' collaborative and technology development activities have already begun yielding benefits in ground-based applications and should continue to do so through FY 1998.

During FY 1997 and FY 1998, the space physiology and countermeasures activities will concentrate on the problems associated with extended stays in space, especially stays of 90 days to 180 days, in preparation for the ISS era. Studies may include human and animal subjects. Budgetary resources will support both basic and applied research on the effects of hypogravity and hypergravity. The project will seek new techniques for the non-invasive, in-flight measurement of the variables that characterize all systems. It will also address the development of an optimal exercise protocol for space flight to provide comprehensive countermeasures to the various physiological and psychological systems, including cardiovascular, musculoskeletal, neuromuscular function, fluid and electrolyte balance, and performance, while minimizing demands on crew time.

During FY 1997 and FY 1998, the space biology efforts will maintain focus on advancing fundamental knowledge in the biological sciences using the tool of gravity and microgravity. Investigations, including renewals and new awards, will concentrate on the areas of cell biology, developmental biology. and comparative and plant biology. Cell biology investigations will examine how gravitational information is transduced, how cells respond to acute and long-term variations in gravity, and how gravity affects the composition, size, shape, and function of cells. Developmental biology investigations will study the influence of gravity and microgravity on animal growth, development, reproduction, genetic integrity, life span, senescence, and subsequent generations of animals. Comparative and plant biology will conduct research to understand how animals and plants perceive, transduce, and respond to gravitational force. The investigations will elucidate the role of hypergravity and microgravity in developmental and reproductive processes and will seek to understand the role of hypergravity and microgravity in such areas as the metabolism and transport processes in animals and plants.

The environmental systems and technologies tasks will refocus their ground-based activities during FY 1997 and FY 1998 toward the development of technologies that will not only support specific needs during the ISS era, but also addresses the strategic thrusts of the Human Exploration and Development of Space Enterprise. Life Sciences environmental systems and technologies programs include the environmental health program, the radiation health program, the space human factors program, the advanced life support and advanced EVA programs, and the Advanced Technology Development (ATD) program.

The environmental health activities will conduct research that will help to establish space flight environmental standards for human health and performance. The project will use FY 1997 and FY 1998 resources to define physiological norms for atmospheric gases, identify toxicants and describe microbial populations (including their numbers, pathogenicity, or products). The program will emphasize investigations of optimal nitrogen washout protocols, and it will rely upon ground-based studies to anticipate the effects of closed systems in space.

During FY 1997 and FY 1998, the radiation health project will support ground-based experimental radiobiology studies using proton and high-energy heavy ion beams. FY 1997 and FY 1998 resources will support studies attempting to understand the mechanisms responsible for radiation-caused carcinogenesis and the reliability of interspecies extrapolation of radiobiological effects. The radiation health program initiated a new collaborative venture with the National Cancer Institute during FY 1996 that will continue during the budget period. This new NASA/National Cancer Institute (NCI) collaborative effort will provide up to $2.0 million per year of research funding through FY 2000, with each agency contributing equally. The collaborative project will attempt to define and understand the nature and extent of long-term genomic instability in mammalian cells caused by chronic low-dose radiation exposures of the kind likely to be encountered during extended space flight and in certain occupational settings. The radiation health project has also approved a series of accelerator 'missions' at the Brookhaven National Laboratory, using the Alternating Gradient Synchrotron. These 'missions' will take place during FY 1997 and FY 1998. The investigations at Brookhaven will succeed a successful set of experiments completed during FY 1995, and will require approximately 150 hours of beam time each year to support the radiation health investigators funded jointly with the NCI.

During FY 1997 and FY 1998, the space human factors project will emphasize both research and technology development. The program will conduct research to document human performance responses to long-term space fight, including especially those that affect the performance of safety-critical functions. This research will attempt to understand the factors that influence space-based performance. The program's research activities will use human-machine scenarios, models, analogs, and other tools as aids in defining human habitability requirements for space flight and in developing design and performance requirements for equipment, procedures, operations and environments in space and on the ground. The project will support the development of new designs, technologies, and systems needed for space and ground-based operations with particular emphasis on advanced displays and controls, human-machine function allocation, interactions among intelligent agents, and intravehicular activity and extravehicular activity.

The primary emphasis of the advanced life support project during FY 1997 and FY 1998 will be on technology areas that have clear and compelling relevance to NASA during the ISS era and that will enable the Human Exploration and Development of Space. The project will demonstrate the feasibility of using higher plants to provide air, water, and food for planetary surface life support systems, demonstrate the maturity of physical/chemical recycling processes for providing air and water for planetary life support

systems and complete the evaluation of continuous cropping of potato and wheat, including the recycling of nutrients from inedible plant biomass through aerobic bioreactors.

During FY 1996, JSC completed Phases I and II of the 'Early Human Test Initiative,' a month-long test of four volunteer test subjects in a closed-chamber demonstration of physical-chemical life support system technologies. During FY 1997. NASA expects to conduct an additional 60-day ground-based demonstration of regenerative life support systems with four test subjects in a closed chamber, also at JSC. At KSC, during FY 1996, a study was completed on the long-term growth of potatoes as a potential food crop for life support systems for planetary exploration and development. Of particular note was a study on recycling plant biomass to supply the nutrients required for plant growth.

To support the advanced life support project's primary emphasis on large-scale bioregenerative validation and testing, the Research and Analysis program budget request includes $2.0 million in FY 1998 to support the conversion of the Weightless Environment Training Facility (WETF) at JSC for the proposed Bio-Regenerative Planetary Life Support Systems Test Complex (Bio-Plex) in the rotunda and east service wings of the WETF. Functions previously carried out in the current WETF are being relocated to the new Sonny Carter Training Facility, leaving most of the rotunda and east service wings of Building 29 at JSC unoccupied. A facilities study performed at JSC documented that facility modifications necessary to install the new Bio-Plex in the rotunda and east service wing rather that at the site of the existing Human-Rated Test Facility would yield construction cost savings of $1.8 million.

During FY 1996, the advanced EVA systems project was restructured in an effort to revalidate its programmatic objectives. This included integrating all advanced EVA elements in the agency and transferring program management to JSC. FY 1997 resources will support proposals in the following areas: mission requirements definition: EVA human factors: physiological and medical requirements: EVA task requirements: systems studies: and EVA mission operations. Activities in this project area, pending the outcome of revalidation activities, will support such initiatives as the development of next generation EVA systems technologies.

The primary emphasis of the advanced technology development (ATD) project during FY 1997 will be on environmental sensors and biosensors. The ATD project will concentrate in particular on developing new technologies for air and water monitoring and microbial detection, as well as refining and micro-miniaturizing currently available sensors. The program will also support the development of advanced implantable biotelemetry systems.

During FY 1997 and FY 1998, the data analysis project will maintain its primary emphasis on extended data analysis and on enabling the research community's access to data. Secondary emphasis will be on the area of special data analysis techniques. NASA and NIH collaborations have yielded particularly fruitful results in Life Sciences' data analysis program, and the program will seek to build upon these past successes. SPACELINE bibliographic database capabilities will expand during the budget period, owing to the continued support provided by the National Library of Medicine. Enhancements will be made to the Life Sciences flight data archive, introduced during FY 1996, and additional database products will be developed in FY 1997 and FY 1998 for the benefit of the research community during the era of the ISS.

During the past year, Life Sciences successfully recompeted NSCORTs in gravitational biology, bioregenerative life support, and environmental health. North Carolina State University in Raleigh received a new NSCORT award for gravitational biology, and an additional gravitational biology NSCORT was established at Rice University. Wake Forest University will be a collaborating partner in the North Carolina State University NSCORT, while the JSC will be a collaborating partner with the new Rice University NSCORT. Rutgers University received an NSCORT for bioregenerative life support, and the Stevens Institute of Technology in Hoboken, New Jersey will be a collaborating partner. The new NSCORTs have received five year awards that were initiated during the first half of FY 1996. During FY 1997 Life Sciences expects to award an additional NSCORT for radiation health. Site visits and selection for the proposed radiation health NSCORT will take place during the first and second quarters of FY 1997.

During FY 1996, NASA and the NCI continued their co-sponsorship of applied research and development projects designed to lead to new breast cancer digital imaging techniques. Deriving from a long-standing agreement between NASA and the NCI, innovative breast cancer imaging techniques that were recently selected from a NASA/NCI competitive solicitation are expected to lead to highly effective, low-cost diagnostic technologies. This collaborative venture will continue in FY 1997 and FY 1998. The payoff from this effort might be huge. Recent statistics show that 186,000 new cases of breast cancer were diagnosed in the U.S. alone in 1993. Health care costs associated with breast cancer in the U.S. exceed $8 billion annually.

An active Research and Analysis-based outreach project is planned for FY 1997 and FY 1998, including outreach activities designed to attract Native Americans to careers in the space life sciences and related engineering disciplines. Outreach programs for Native Americans attempt to develop the telecommunications information infrastructure of Tribal educational organizations. Life Sciences initiated a Native American Earth and Space Academy (NAESA) during FY 1996, and began work on providing Internet connectivity to the Navajo Community College and the Headquarters of the Cherokee Nation of Oklahoma's Sequoyah High School. Finally, Native American outreach programs will team with the Air Force Office of Scientific Research to support the Navajo Community College Telecommunications Infrastructure Development program during FY 1997, along with the planning for the All Indian Nations Forum on Telecommunications.

The Research and Analysis program will continue to encourage extramural investigators to take advantage of NASA-unique facilities to support research objectives. The program will use FY 1997 and FY 1998 budgetary resources to increase extramural access to the Biocomputation Center, the Vestibular Research Facility and other radial acceleration facilities at the ARC, along with the KC-135 fight program and other biomedical facilities at the JSC.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### LIFE SCIENCES FLIGHT PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Life sciences flight experiments program ..... | 54,400 | 39,400 | 35,500 |

### PROGRAM GOALS

The Life Sciences Flight Experiments program systematically manages and supports investigations with living systems that require access to the unique characteristics of low-Earth orbit. The program secures timely space flight opportunities for the space investigations it sponsors. The science supported by the program uses microgravity and the other characteristics of the space environment to enhance understanding of fundamental biological processes. In addition, the program's flight research and technology development work provides the scientific and technological foundations for a safe, productive human presence in space for extended periods.

### STRATEGY FOR ACHIEVING GOALS

The Life Sciences Flight Experiments program strives to select and develop the highest-quality research and technology. The program solicits a steady stream of new research and technology investigations, manages and supports them during pre-flight definition, development, and through post-flight activities. The program relies upon peer reviews to determine which science research and technology to endorse. Its peer review process in recent years has become a cooperative enterprise with the National Institutes of Health (NIH). Cooperative enterprises such as those with the NIH and other external partners ensure that flight opportunities are provided to the highest-ranked, peer-reviewed research and technology projects.

The Life Sciences Flight Experiments program provides a balanced and robust series of flight opportunities which include human-assisted or human-subject flight opportunities aboard the Space Shuttle as well as research opportunities aboard unmanned vehicles. The program uses Spacelabs that fly in the Space Shuttle cargo bay as well as the Space Shuttle middeck for small payloads. As the nation approaches the era of the ISS, the Life Sciences Flight Experiments program is taking advantage of longer-duration flight opportunities aboard the Mir space station. The NASA/Mir Research program (NMRP) investigations will enable the Life Sciences Flight Experiments program to conduct research, develop technologies, and help mitigate the risks of long-duration space flight. In the ISS era, crews will remain on orbit for as long as 180 days at a time: the Life Sciences Flight Experiments program will provide enabling technologies to take maximum advantage of this long-duration opportunity.

The Life Sciences Flight Experiments program develops and supports investigations in the areas of biology, physiology, environmental health, and behavior and performance for Spacelab flight opportunities. The program's budgetary resources enable necessary pre-flight planning, development, and support for selected investigations. Program resources provide for post-flight

services and appropriate data analysis and distribution, including the development of specialized databases and archiving services to ensure that flight research findings and results are widely available to the research community.

In FY 1996, Life Sciences participated in the Life and Microgravity Spacelab (LMS) mission. The last scheduled life sciences Spacelab flight is Neurolab, scheduled for the second quarter of FY 1998. The Neurolab mission will conduct basic research in sensory-motor, vestibular function, spatial orientation, developmental biology, nervous system plasticity, autonomic nervous system control of the cardiovascular system, sleep and circadian rhythms, and human behavior.

The Life Sciences Flight Experiments program also relies upon Space Shuttle small payload opportunities to supplement flight opportunities that Spacelab provides. The objectives of small payload flights are to provide scientists and researchers with opportunities to fly their research quickly and economically, via the Space Shuttle middeck. The science conducted may be in plant biology, space physiology and countermeasures, developmental biology, cellular research, human factors, and performance disciplines. Most of the research uses existing flight hardware. Small payload opportunities demonstrate hardware performance or develop research techniques for the Spacelab, the NMRP, and the Space Station. NASA anticipates that, once the Space Station becomes operational, small payload-class investigations will migrate to the Space Station's EXPRESS rack program.

In cooperation with the Russian Space Agency (RSA) the Life Sciences Flight Experiments program conducts biological experiments with non-human primates on unmanned biosatellites. The Bion spacecraft series of biosatellites flies biological and radiation measurement experiments in near-Earth orbit. Since 1973 the Russian Federation (formerly the U.S.S.R.) has launched eleven biosatellites: the U.S. has participated in the last nine missions and is scheduled to participate in the upcoming Bion 12 mission. The major objectives of the Bion investigations are to study the biological effects of microgravity and radiation on living systems: to evaluate living systems' adaptation to microgravity and other characteristics of space; and to evaluate the fundamental characteristics of living systems, using gravity as a variable. Bion missions with primates last up to fourteen days.

## Contractor and Center Support

The participating Field Centers in life sciences' flight research activities and programs include the Johnson Space Center (JSC), which leads the development and support of life sciences investigations in the areas of space physiology, environmental and human factors, and advanced life support. The Ames Research Center (ARC) leads the development of space biology research investigations and plays the primary life sciences role in the development of primate investigations scheduled for launch aboard biosatellite missions. Both of these NASA Centers participate in Spacelab flights, small payloads, NMRP, and the Space Station. The Kennedy Space Center (KSC) manages life sciences payload integration, provides pre- and post-flight support, manages advanced life support facilities and demonstrations, and manages small payload investigations, especially those using plants.

## International & Domestic Cooperation

The Life Sciences Flight Experiments program seeks opportunities to enhance its science research and technology development activities by promoting cooperative activities with researchers and research organizations. Life Sciences' collaborative activities with non-NASA entities include foreign partners participating in the ISS program, as part of the effort to build and enhance

working relationships in preparation for the Space Station era. NASA and the ESA. for example, will both fly investigations on the ESA-built Biorack during the NMRP. On the LMS mission, the new Department of Defense-built cell culturing system was flown. On the same flight, the Torque Velocity Dynamometer developed by ESA was flown for the first time to conduct musculoskeletal and combined musculoskeletal and neurophysiological experiments. On the Neurolab mission, 10 of 32 investigators selected for development are international: investigators from Germany, Japan, Italy, France, and the Netherlands are participating. ESA [Europe), NASDA (Japan),CNES (France),DARA (Germany),and CSA (Canada) are developing Neurolab flight hardware. Domestic Neurolab participation will come from NIH, which is playing a leading role in Neurolab science management and development, the National Science Foundation, and the Office of Naval Research.

International and domestic partners also play vital roles in the Life Sciences Flight Experiments program's small payloads program. The French, Russian, German, Ukrainian, and Canadian Space Agencies represent about 25% of the annual small payloads investigator population. The small payloads program uses flight hardware provided by other federal agencies, such as the Walter Reed Army Institute for Research, along with hardware from Canada and Germany.

**MEASURES OF PERFORMANCE**

| | FY 1996 | | FY 1997 | | N 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Revised | plan |
| Number of Flight Principal Investigators | 148 | 167 | 134 | 164 | 138 |
| Number of Investigators Flown | 63 | 63 | 43 | 62 | 60 |

The LMS Spacelab mission flew on STS-78
Plan: 3rd Qtr N 1996
Actual: 3rd Qtr FY 1996

The LMS flight supported the non-Rhesus science that had been scheduled to fly on the SLS-3 mission. The mission supported musculoskeletal and behavior and performance investigations to build on the research results of the successful SLS-1 and SLS-2 missions.

The Neurolab mission will fly on STS-90
Plan: 2nd Qtr FY 1998

The Neurolab science payload focuses on the effects of weightlessness and other aspects of the space environment on developmental and cellular neurobiology, vestibular function, spatial orientation and visuo-motor performance, autonomic nervous system regulation, sleep and circadian rhythms, and learning and behavior.

The U.S. will share 50% of the science from the Bion 11 and Bion 12 mission

Bion 11
Plan: 1st Qtr FY 1997
Actual: 1st Qtr FY 1997

Bion 12
Plan: 1st Qtr FY 1999

Bion 11 and Bion 12 will accommodate the Rhesus investigations that had been scheduled to fly on SLS-3. The Bion 11 and Bion 12 investigators will conduct musculoskeletal, neurosensory, immunology and regulatory physiology investigations.

**ACCOMPLISHMENTS AND PLANS**

During FY 1996, a major emphasis of the Flight Experiments program was the support of the LMS mission. LMS flew on STS-78, launched in June 1996. The LMS mission provided for sixteen integrated Life Sciences experiments (including small payload investigations) in the musculoskeletal, cardiopulmonary, metabolic, behavior and performance, neuroscience, and space biology research disciplines. Of the sixteen, nine were U.S. biomedical research and three were U.S. space biology. Four were sponsored by international agencies. LMS post-flight data analysis will be conducted during FY 1997. These data will be compared with data from the ground-based science study performed the previous year and with certain experiments on Bion 11.

The LMS mission is also noteworthy for the range of collaborative arrangements that improved science and minimized costs. ESA's Torque Velocity Dynamometer, ESA's Hand-Grip Dynamometer, the Canadian Space Agency's Torso Rotational Experiment, and the French Space Agency's Canal and Otolith Interaction Studies flew on the LMS mission. The crew of the LMS mission included two international payload specialists, one from Canada and one from France. Their backups were from Italy and Spain. Remote payload operations successfully tested concepts that Life Sciences expects to apply on the ISS.

The Life Sciences Flight Experiments program continued Neurolab science planning and mission development activities during FY 1996, and the program continues on target for an FY 1998 flight aboard STS-90. The Neurolab mission is a key collaborative venture between NASA and other domestic Federal science agencies during the "Decade of the Brain." The NIH, the NSF, and the Office of Naval Research are providing funding to seventeen of the twenty-two domestic investigations that Life Sciences is now supporting for Neurolab flight development. A total of thirty-two investigations have been selected for Neurolab development, ten of which are being funded by NASA's international partners.

The Neurolab science payload focuses on the effects of weightlessness and other aspects of the space environment on developmental and cellular neurobiology, vestibular function, spatial orientation and visuo-motor performance, autonomic nervous system regulation, sleep and circadian rhythms, and learning and behavior. Human studies of the crew and animal studies of species housed in specialized facilities will be carried out. Six of Neurolab's thirty-two Life Sciences investigations do not require the full laboratory resources of a Spacelab flight and will instead be carried out as small payload experiments.

Four Neurolab payload specialist candidates were selected from twenty-five nominees and began their training during FY 1996. Two of these will be selected as payload specialists during FY 1997 and the other two will serve as alternates. Two mission specialists were assigned to the crew during FY 1996 and began training. During FY 1996, ARC and JSC carried out critical design reviews and ground-based flight simulation control studies. Final selection of Neurolab flight experiments will occur during FY 1997, one year prior to flight. Integrated design reviews of experimental hardware for the final stages of hardware development prior to integration and flight will take place during FY 1997.

During FY 1996, the Life Sciences Flight Experiments program flew eleven small payload investigations in musculoskeletal physiology, plant biology, and developmental biology. The NIH/Cells series of investigations continued during FY 1996 with the flights of NIH/Cells-5 and NIH/Cells-7. The program also participated in the NIH/Rodent-3 mission, which was a verification flight for Neurolab. The Aquatic Research Facility, belonging to the Canadian Space Agency, was flown in addition to two plant biology experiments, for a total of six FY 1996 small payload middeck opportunities. FY 1997 and 1998 resources will continue to provide for an active life sciences small payloads program. FY 1997 resources will support the continuation of the NIH/Cells and NIH/Rodent series of investigations (using rodents, cells, and plants) along with additional life sciences small payload investigations and data analysis, for a total of six FY 1997 small payloads investigations. FY 1998 will begin with the Collaborative Ukrainian Experiment (CUE), which is a plant payload. CUE involves five U.S. Principal Investigators and seven Ukrainian Principal Investigators sponsored by the National Space Agency of Ukraine. A Ukrainian Payload Specialist has been selected to perform all in-flight operations.

**Bion Program**

FY 1997 resources are providing for completion of the development, testing, and delivery of flight hardware to Russia in support of the December 1996 launch of the Bion 11 biosatellite mission. The mission has flown some of the primate experiments from the canceled SLS-3 Spacelab mission. It is designed to expand our understanding and knowledge of a variety of biomedical problems in humans. It will be used to investigate the effects of weightlessness on bone, muscle, and neuromuscular structure and function, sensory-motor function, behavior, circadian rhythms, fluid and electrolyte balance, and immunology. In January 1996, the Life Sciences program exercised the option to fly the Bion 12, a mission identical to Bion 11, which will fly during the first quarter of FY 1999, thereby completing the SLS-3 primate studies.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### MICROGRAVITY RESEARCH AND ANALYSIS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Microgravity research and analysis ..... | 30,200 | 31,900 | 36,500 |

### PROGRAM GOALS

The Microgravity Research and Analysis (R&A) program seeks to understand basic physical phenomena and processes, quantify effects and overcome limitations imposed by gravity on the observation and evaluation of selected phenomena and processes: develop technologies related to the requirements of the research: and expand, centralize and disseminate the research data base as widely as possible to the U.S. research and technology community. The primary goal of the R&A program is to mature the research of a large number of laboratory scientists into coherent groups of flight experiments for the Space Station and research other opportunities. The R&A program is designed to establish the intellectual underpinning of the flight program. In order to do this, a multi-disciplined research program has been established in the areas of biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science. Ground-based experiments, coupled with experiments selected for flight definition, comprise a compelling and coherent strategy for utilization of the space environment.

### STRATEGY FOR ACHIEVING GOALS

The Microgravity Science and Applications mission to develop and utilize the scientific potential of space, ground-based research serves two purposes: to find and refine concepts for space experiments, and to create a framework of knowledge and expertise in which the full scientific value of space experiments can be realized. The R&A program, through its support of ground-based research, provides the genesis from which strong, well-defined flight experiments emerge. The strategy NASA has devised for achieving excellence in microgravity research is to utilize the nation's academic and industrial resources, joining prominent researchers with NASA expertise in multidisciplinary microgravity experimentation. The mechanism to engage national scientific resources is the release of NASA Research Announcements (NRAs), solicitations directed to research disciplines, inviting proposals for research and flight experiment concepts. Proposals are selected by peer panels of technical experts on the basis of scientific and technical merit and need for the microgravity environment. By soliciting for research across a discipline, rather than for specific missions, NASA allows easier entry into the microgravity program for researchers with strong merits but limited experience with the space program. Approximately 80% of the R&A budget funds research grants and contracts which are awarded through competitive peer review, with over 90% of this funding going to external investigators across the United States. The remaining 10% is used at NASA field centers to provide supporting infrastructure. NASA set out at the beginning of the 1990's with the goal of building a research program that seeks to exploit the microgravity environment possible through space flight, engaging the talent and energy of the nation's scientists and engineers to develop the potential of space for research in physical, chemical, and biological processes. Having established a strong foundation for this effort through a series of highly-successful research

solicitations, NASA is working with the science and engineering community to define and build a dynamic, coherent research program. Since the inception of the R&A program in 1989, 14 NRA's covering five disciplines have been released, and over 2500 proposals have been received. Approximately 300 Principal Investigators are now in the peer-reviewed Research and Analysis ground-based program.

The five science disciplines which comprise the Microgravity R&A program are biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science.

The biotechnology project focuses on protein crystal growth, cell sciences, and fundamentals of biotechnology as areas which offer promising opportunities for significant advancements through low-gravity experiments. Experiments in space have demonstrated that gravity influences protein crystal growth and that reduced gravity can result in improved crystal characteristics. Improved data from protein crystals will allow scientists to better understand protein structures, a critical element of structural biology and rational drug development. Cell science technology explores the cellular response to low stress environments in a technology central to contemporary biomedical research. Growing normal and cancerous mammalian tissues is a technology with enormous medical benefits and applications. Fundamentals of biotechnology is an area of exploratory research in new directions such as transport of material across membranes. Information from this research may be significant in improving the efficiency of rational drug design.

The combustion science project focuses on combustion, which is responsible for producing 85% of the world's energy as well as a significant fraction of atmospheric pollution. Pollution is a continuing hazard to life and property on Earth and in space. Combustion reactions release heat. Under gravity's influence, heat release during combustion causes a convective flow as the heated gas rises. By reducing this flow in a low gravity environment, important problems such as soot formation in flames, the spreading of fires, the burning of hydrocarbons and limits of flammability can be studied in very fundamental ways. The applications of this research to fire safety and control are becoming significant.

The fluid physics and transport phenomena project studies the properties and motions of liquids and gases, providing a conceptual framework in which to understand the role of gravity in physical and chemical processes. The program also provides a foundation for advances in technologies required for exploration and development of space, such as regenerative life support systems, utilization of local resources, propulsion systems, power generation, cryogenic and fluid management. Scientists study how fluids flow under different conditions, how energy affects fluid flows, and many other important scientific and practical issues. Investigators seek the ability to make accurate predictions of how heat and mass are transported in mixtures of fluids and vapor, with profound implications for production and control processes on Earth and in future space engineering applications.

The fundamental physics project includes the study of critical phenomena, low-temperature physics and other phenomena for which the space environment can make possible measurement of physical constants with levels of accuracy that challenge the contemporary theories in physics. Reduction and control of the forces due to gravity allow investigations to probe into the depths of physical variables to levels that allow the verification of universal theories which can then be used in a great many fields of physics with much greater confidence. This part of the microgravity program addresses science and technology issues on the forefront of physics research and includes research topics at the frontier of our knowledge.

The materials science project examines the relationship between processing, structure and properties, and strives to acquire the basic knowledge required to develop new generations of high performance materials in areas including electronic and photonic materials, glasses and ceramics, metals and alloys, and polymers and nonlinear optical materials. Materials can be divided into crystalline (acertain long range order on the atomic scale) and non-crystalline or amorphous (no long range order). The properties of a material are largely determined by the structure of the material, and are greatly influenced by the process used in forming the material. Gravity-driven phenomena can play a huge role in this triangle of properties/processing/structure. Utilization of the low gravity environment to give insight into materials and materials processing may result in improvements to production methods and materials on Earth. The materials science research program provides the baseline for comparison with future microgravity research and identifies the deficiencies in our knowledge of materials behavior on Earth.

## Collaborative Activities

Through collaboration with domestic and international science communities, the R&A program has sought to obtain concrete as well as synergistic investments by other participants. NASA has joined with the National Institutes of Health (NIH) to obtain laboratory space, diagnostic equipment, and skilled researchers to accelerate the transfer of NASA-developed bioreactor technologies to the broader science community. Through joint cooperative agreements with private industry, NASA has acquired market-valued protein derivatives and diagnostic equipment which support both industrial and government sponsored research in areas of protein crystal growth. Letters of agreement with Japan and Canada have improved the research facilities available to United States ground-based principal investigators. The Japanese have made their highly sophisticated 10-second drop tower facilities available to a broad range of United States combustion science investigators. This facility extends the capability of the 5-second drop tube in the U.S. The Canadian Space Agency has developed and offered to the United States a large vibration isolation mount that can be used in United States parabolic aircraft to provide an improved lower gravity environment on the aircraft which is an integral part of the ground-based research program.

## Center and Contractor Support

Consistent with NASA's field Center mission assignments, Marshall Space Flight Center (MSFC) is the Microgravity Research Program lead center and also a center of excellence for the materials science and biotechnology portions of the program. The Johnson Space Center (JSC) contributes to the biotechnology research program by conducting research in the cell culturing area. The Lewis Research Center (LeRC) is the center of excellence for combustion science and fluid physics and transport phenomena disciplines. The Jet Propulsion Laboratory (JPL) is a center of excellence and is responsible for the fundamental physics portion of the program. Contractors are utilized for science support at the Centers and are responsible for understanding and monitoring certain investigators' science. They also assist the external scientists in the utilization of unique facilities at the centers required to carry out some of the low gravity experimentation.

## MEASURES OF :E

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Revised | plan |
| Number of Ground-Based Principal Investigators | 260 | 261 | 290 | 290 | 300 |
| Number of Co-Investigators supported (Ground-Based and Flight) | 300 | 259 | 330 | 330 | 340 |
| Number of Graduate Students supported (Ground-Based and Flight] | 540 | 544 | 600 | 600 | 615 |
| Number of Refereed Publications (Ground-Based and Flight) | 1200 | 1216 | 1320 | 1320 | 1360 |

| | |
|---|---|
| Completed 134 peer-reviewed studies in the disciplines of Biotechnology, Fluid physics and Transport Phenomena, Materials Sciences and Advanced Technology in FY 1996 | A summary assessment of the results of these studies, which focus on macromolecular crystal growth as well as cellular response to low stress environments, will be included in the Annual Program Task and Bibliography of the NASA Technical Memorandum for FY 1996. |
| Complete 31 peer-reviewed studies in Combustion Science Plan: September 1997 | A summary assessment of the results of these studies, which focus on processes of ignition, propagation and extinction during combustion in a low gravity environment, will be included in the Annual Program Task and Bibliography NASA Technical Memorandum for FY 1997. |
| Complete 17 peer- reviewed studies in Combustion Science plan: September 1999 | A summary assessment of the results of these studies, which focus on processes of ignition, propagation, and extinction during combustion in a low-gravity environment, will be included in the Annual Program Task and Bibliography NASA Technical Memorandurn for FY 1999. |

## ACCOMPLISHMENTS AND PLANS

NASA continued investigations selected from the 1994 fluid physics, materials science, and combustion science NRAs. As these disciplines enter a period of consolidation following vigorous growth in the early 1990's, NASA plans only modest budget increases that will allow for discipline maturation. The investigations currently supported will define the first phase of space station rnicrogravity research. Further growth in these disciplines is planned toward the end of the decade, when it is anticipated that space station research will grow in scope and intensity.

N SA released the third Microgravity Biotechnology NRA. One hundred thirty proposals have been received and are undergoing peer-review for a selection of approximately 30 new awards in April 1997. The Biotechnology NRA will provide a definitive opportunity for experiments in protein crystal growth and tissue culturing, as well as a broadening of the field into fundamental studies of other areas of biotechnology. Several of these research tasks are cooperative efforts with the National Institutes of Health (NIH).

Research into new technologies for x-ray diagnostics of protein crystals has resulted in the development of a new brilliant x-ray system. This new system is capable of producing a focused x-ray beam that is more than 50 times brighter than conventional beams at a fraction of the power consumption. This new technology is so promising that a proposal has been submitted to expand the development to make the system available to ground-based laboratories throughout the research community. This new proposal is a venture including NASA, industry, academia, and the NIH.

*An* agreement was signed between NASA and NIH for the use of a laser light scattering diagnostic instrument in the Microgravity Fluid Physics Program. NIH, via its National Eye Institute, will use the probe for early detection and diagnosis of eye diseases such as cataracts, diabetic retinopathy, and the inflammatory diseases of the anterior chamber of the eye.

NASA made awards to 17 academic, industrial, and governmental institutions for microgravity combustion science investigations. The awards range from basic scientific research, to the development of advanced instrumentation that will be of use not only to the microgravity research community but to terrestrial research and applications as well. New topical areas include the study of flame-synthesized fullerenes in microgravity (the material for which the Nobel Prize in Chemistry was recently awarded) and metals combustion in microgravity. These will be conducted for the next four years, with extensive utilization of NASA's drop towers and low-gravity aircraft in order to perform microgravity experimentation.

A patent was awarded to researchers at Lawrence Berkeley National Laboratory, under contract to NASA Lewis Research Center for the performance of microgravity combustion science research, for their new method to lower pollutant emissions in natural-gas appliances such as residential heating furnaces and hot water heaters. Burners with their "Ring Flame Stabilizer" reduce significantly the emissions of NO, (oxides of nitrogen) that are major contributors to smog and atmospheric contamination. The title of the patent is "Apparatus and Method for Burning a Lean Pre-mixed Fuel/Air Mixture with Low NOx Emission."

Collaborative research between Japan/NEDO and the United States/NASA was established and conducted successfully in the Japanese 10-second drop tower and NASA Lewis Research Center's 2.2-second and 5-second drop towers for investigations of fuel droplets and solid fuel burning. This collaborative research saved substantial resources for each country, by avoiding duplicative construction of hardware, while gaining new scientific knowledge of these phenomena.

NASA awarded 33 investigations in the discipline of microgravity fluid physics and transport phenomena. The selections from the 1994 Fluids NRA represented a 50% increase in the number of ground-based research tasks supported in this program and has introduced new areas of research into the discipline, specifically in the areas of complex fluids, granular flows, and bio-fluids. With the addition of the new investigators, these areas of the broad fluid physics discipline are now approaching a critical mass.

All of the areas in the fluid physics discipline are well aligned with the HEDS enterprise, yielding a fundamental understanding of physical and chemical transport phenomena that are important in the development of space.

NASA awarded 23 investigations in the discipline of fundamental physics. The addition of four investigations of laser-cooled atoms into the fundamental physics program increases the range of basic topics to be studied. These include phenomena occurring in Bose-Einstein condensates and tests of the Standard Model of physics using precise measurements made possible by the very cold temperatures (within $10^{-9}$ degree of absolute zero) of the atomic sample. The growing community of investigators and the maturity of their investigations has led to increases in the number of publications produced, and should also lead to a larger number of proposals for flight experiments in the December 1996 NASA Research Announcement for this discipline.

NASA made awards to 51 microgravity materials science research and analysis investigations. The awards range from basic and applied scientific research to the development of advanced data acquisition and thermophysical condition-generation technology. This selection broadened the established field of microgravity materials science research and analysis, with emphasis on studies of fundamental scientific phenomena and specific classes of materials such as polymers. The awardees will conduct research each year through FY 2000.

In FY 1997 a road map for the Microgravity Research Program, with strategies to accomplish program objectives will be prepared. This road map is analogous to those developed for NASA and the HEDS Enterprise. In addition, road maps for each of the microgravity research sub-disciplines (biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science) will be prepared. The development of these road maps will insure that the Microgravity Research Program is fully aligned with the HEDS and NASA strategic goals. These road maps are the basis for developing the discipline program contents. For each of the three time periods shown in the plan, major activities/milestones will be identified and will define the program content required to meet the stated strategic goal or objective. Subsequently this information will be used in developing the long term Microgravity Program budget requests.

The principal objective for the R&A program in FY 1997 will be to integrate the investigations selected through the three solicitations released in FY 1997 into the ongoing efforts of the microgravity program. NASA will be working with large numbers of external researchers to define flight experiments with high scientific merit, and with advisory groups as well as the community at large to achieve the focus and coherence required of a strong, productive flight program. A productive research program also requires dynamic flexibility to keep pace with the progress of scientific and technological knowledge, and in FY 1997 NASA will continue to stimulate new concepts for microgravity research through its plan for discipline conferences.

Proposals to renew promising continuing research activities, as well as new and innovative research proposals, will be selected by peer review. Proposals selected by peer-review will be judged to be in the ground-based research or flight-definition part of the program, based upon the maturity of their laboratory research and their understanding of the role of the microgravity environment.

Selection of approximately 30 biotechnology proposals for funding is expected in early 1997. NRAs for Fluid physics and Transport Phenomena, Fundamental physics and Materials Science will be released in FY 1997.

NASA plans to continue to increase the number of Microgravity ground-based Principal Investigators in FY 1997. The number of research proposals received is expected to exceed 600 in FY 1997, based upon past submissions and the increasing interest in NASA's microgravity research program. A large portion off these proposals will be from new investigators who believe that the microgravity environment will contribute to their research understanding. Other proposals will be from scientists who have been supported by NASA to perform laboratory research, and whose work is sufficiently mature to be included in the flight definition program.

NASA will be improving its field Center resources in FY 1997 and FY 1998, bringing new and refurbished facilities on line. This activity will strengthen the ability of NASA field Centers to support increasing numbers of investigators interested in conducting microgravity experiments. Approximately 10% of the peer-approved proposals have NASA scientists as Principal Investigators (Pis) or Co-Investigators. These civil service scientists contribute facilities and resources to assist other PIs in accomplishing their research, especially in the flight program.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### MICROGRAVITY FLIGHT PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Microgravity flight experiments program ..... | 76,300 | 73,400 | 64,900 |

### PROGRAM GOALS

The primary goal of the Microgravity flight program is to advance fundamental scientific knowledge in physical, chemical, and biological processes and to enhance the quality of life on Earth by conducting scientific experiments in the low-gravity environment of space. The results derived from experiments conducted aboard suborbital rockets, the Space Shuttle, the Russian Mir Space Station, and the International Space Station (ISS)will spark the imagination of the growing academic and industrial science community, enhance the nation's technological and industrial base, and foster international cooperation.

### STRATEGY FOR ACHIEVING GOALS

Over the last decade, NASA has established an active scientific program in microgravity research utilizing the Space Shuttle as a research tool. As the program moves toward the next century, the focus will shift from use of the Space Shuttle toward use of the ISS. The strategy for accomplishing the transition from the Shuttle to the ISS is to use the Mir Space Station to mitigate risk in scientific, technological, logistical, and operational planning. Today, the microgravity research program is utilizing both the Space Shuttle and the Mir to achieve its objective of providing flight experiment opportunities for investigators who can benefit from conducting experiments in the low-gravity environment of Earth orbit. Microgravity investigations are conducted in the science disciplines of biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science. The flight program provides scientific apparatus (e.g., flight hardware) for experiments for a wide range of flight opportunities in the Space Shuttle middeck, Space Shuttle cargo-bay, Spacelab, Spacehab, the Mir, and the ISS. Experiment apparatus ranges from small hand-held single experiments to multi-rack, facility-classhardware which can accommodate multiple investigators, The program includes selection, definition, development, in-flight operational support, and data analysis/archiving for all microgravity flight experiments. The flight program, in conjunction with the NASA/Mir Research program and the Space Station Research program, comprise the activities necessary to accomplish the Microgravity research flight program in the 21st century.

The flight experiments program meets peer-reviewed science requirements through the development of appropriate infrastructure, experiment apparatus, flight opportunities, and advanced technologies. The flight experiments program develops experiments, supports science operations, and analyzes flight data and samples in all the major Microgravity disciplines. The flight experiments

program fosters cooperative activities with other organizations to combine the research goals of those organizations to generate results from flight experiments which have previously eluded researchers on earth.

NASA is utilizing the ubiquitous presence and capability of the Internet and the World Wide Web (WWW) to generate real-time displays of the microgravity environment. By utilizing the WWW, NASA is able to provide global access to the Shuttle microgravity environment data to all researchers.

## Center and Contractor Support

NASA's FY 1995 Zero Base Review (ZBR) assigned the Agency mission of microgravity to the Marshall Space Flight Center (MSFC). In response to the recommendations of the ZBR, the NASA Headquarters Office of Life and Microgravity Science and Applications (LMSA) and MSFC established the Microgravity Research Program Office (MRPO) at MSFC to provide integrated program planning and management of NASA's Microgravity development program. In addition to its lead center assignment, MSFC is responsible for the execution and project management of the microgravity biotechnology, materials science and glovebox flight programs. Science support at MSFC is provided by the Universities Space Research Association through its member universities and the Alliance for Microgravity Materials Science (AMMSA). Engineering support is provided by various hardware contractors. Under the leadership of the MWO, JSC executes the cell sciences portion of the biotechnology program with contractor support from Krug Life Science Corporation. LeRC executes the combustion science, fluid physics and transport phenomena, and acceleration measurement programs with contractor support from NYMA and Analex Corporations. The fundamental physics program is executed by JPL with support from Stanford University and Ball Aerospace Corporation.

## International and Other Federal Agencies Support

The European Space Agency (ESA) developed the Spacelab module that is used in the United States Microgravity Laboratory (USML), the Life and Microgravity Spacelab (LMS), and the Microgravity Science Laboratory (MSL) missions. Additionally, our international partners developed nearly all of the experiment apparatus that flew on the second International Microgravity Lab (IML-2). That apparatus was shared by both international and United States investigators.

The Spacelab glovebox that flew on USML-2 was developed by ESA and, in exchange for U.S. use of this glovebox on USML-2, NASA has twice flown two units of the ESA Advanced Protein Crystallization Facility (APCF) in the middeck of the Space Shuttle. Both U.S. and European investigators used the APCF on this quid-pro-quo agreement with ESA. In addition, an agreement is being negotiated with ESA for additional flights of the APCF. Each flight was for two APCF units with a total of 96 protein crystal growth cells where the U.S. investigators would get 48 cells.

Research aboard the LMS mission in biotechnology, fluid physics and transport phenomena, and materials science allowed United States investigators to use instruments developed by ESA, broadening the basis for international cooperation in space research. Both United States and international investigators used the European-developed Isothermal Dendritic Growth Experiment (IDGE), Material pour l'Etude des Phenomenes Interessant la Solidification sur Terre et en Orbite (MEPHISTO), and the Advanced Gradient Heating Facility (AGHF) to conduct numerous materials science experiments.

The MSL-1 mission will conduct materials science research using the National Space Development Agency of Japan (NASDA)-developed large isothermal furnace and the German-developed Tiegelfreies Elektromagnetisches Prozessieren Unter Schwerelosigkeit (TEMPUS) hardware. Both United States and international investigators will utilize this hardware during MSL-1.

The USMP-4 mission will conduct materials science research using internationally developed hardware that flew on previous USMP missions which has been upgraded to conduct new peer-reviewed science experiments.

NASA and ESA are jointly conducting a definition study of the Satellite Test of the Equivalence Principal (STEP) experiment, which will be a candidate for an ESA mission in the 2001-2003 time frame. The Microgravity Science Payload (MSP-1) mission, scheduled for February 2001 will include a reflight of up **to** two MEPHISTO furnaces, with both United States and international investigators, as well as reflights of other United States materials science experiments.

The NIH has invested billions of dollars of ground-based research in cell culturing. The NASA/NIH agreement on the use of NASA's bioreactor technology allows NASA to take advantage of this significant investment and analysis base to extend the understanding of structure and functions applicable to cell culture flight experiments using the NASA-developed bioreactor.

**MEASURES OF PERFORMANCE**

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Revised | plan |
| Number of Flight Principal Investigators | 40 | 36 | 40 | 40 | 40 |
| Number of Investigators Flown | 23 | 23 | 23 | 25 | 6 |

| | |
|---|---|
| USML-2 Launch<br>Plan: 4th Qtr FY 1995<br>Actual: 1st Qtr FY 1996 | USML-2 focused on the physics of crystallization, fluid dynamics and biotechnology. Investigations continued from the highly successful USML-1 mission (6/92), as well as new investigations chosen since that time. |
| USMP-3 Launch<br>Plan: 2nd Qtr FY 1996<br>Actual: 2nd Qtr FY 1996 | The USMP-3 mission focused on experiments in microgravity materials science and included reflight of the AADSF, IDGE, MEPHISTO, and Zeno. Both European and U.S. investigations were conducted. |
| Life and Microgravity Sciences Mission (LMS) Launch<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | The LMS mission was the first flight of the ESA Advanced Gradient Heating Furnace (AGHF), a new furnace facility available to NASA to conduct materials science investigations selected in 1992 on the physics of multiphase solidification. Several ESA investigations were also conducted. The Bubble Drop and Particle Unit also supplied by ESA supported a wide range of fluid physics investigations. |

| | |
|---|---|
| Microgravity Science Laboratory (MSL-1) Launch Plan: 2nd Qtr FY 1997 | The MSL-1 flight will carry major NASA-developed instruments for research in combustion science and fluid physics (Combustion Module-1 (CM-1), the Droplet Combustion Experiment (DCE) and the Physics of Hard Spheres Experiment (PHASE)). These investigations explore phenomena central to pollution control, engine efficiency, fire safety, and phase transformation. Using both German and Japanese-developed hardware and both U.S. and international investigators, materials science investigations will continue investigations which were begun on IML-2. |
| USMP-4 Launch Plan: 1st Qtr FY 1998 | The USMP-4 mission will focus on experiments in microgravity materials science and will be a reflight of hardware from the USMP-3. Both European and U.S. investigations will be conducted. |

**ACCOMPLISHMENTS AND PLANS**

The major FY 1996 efforts in the Microgravity Research Flight Experiments Program were focused on the USMP-3 Spacelab and LMS missions. USMP-3 included the same complement of experiment facilities as USMP-2: three solidification furnaces, each of which is designed to examine a different type of crystal growth, and a fluids facility. While the majority of the hardware is the same, the scientific research is new. Principal Investigators have used the data from USMP-2 to redesign experiments to probe more deeply into phenomena that yielded numerous scientific insights.

Research aboard the LMS mission in biotechnology, fluid physics, and materials science allowed U.S. investigators to use instruments developed by ESA, broadening the basis for international cooperation in space research. The LMS mission was the first to fly the ESA Advanced Gradient Heating Furnace (AGHF), a new furnace facility of significant interest to the U.S. science community available to NASA through international cooperation. The AGHF was used by NASA to conduct two materials science investigations selected in 1992 on the physics of multiphase solidification. Several ESA investigations were also conducted. The Bubble, Drop and Particle Unit (BDPU) was modified and used to conduct two new NASA investigations, as well as experiments sponsored by ESA. NASA protein crystal growth project conducted two new types of experiments on the 16-day mission.

In August 1996, the Agency decided to terminate, by July 1997, the dedicated use of the leased DC-9 based at Lewis Research Center for providing parabolic aircraft flight support to NASA's microgravity research program. As the Microgravity Lead Center, the Marshall Space Flight Center (MSFC) has been directed to validate the parabolic aircraft requirements (annual flight hours needed) for all NASA-sponsored microgravity research (both Microgravity Research and Space Product Development, and to develop an implementation plan for providing parabolic support to NASA's microgravity research program. The plan, to be in place prior to termination of the DC-9 agreement, will include the details for return of the DC-9 to the lessor, and address the validation of all Agency KC-135 requirements.

## Biotechnology

During FY 1996, the Biotechnology Program supported 20 experimental instrument flights in protein crystal growth and cell science. More than 1500 protein samples were flown by three Principal Investigators and numerous Guest Investigators. This large number of samples provided opportunities for investigators to use multiple sample protocols and build a statistical basis for their investigations. Several samples were flown to help develop a system that will investigate the fundamental mechanisms by which protein crystals form. This knowledge will assist not only investigators growing crystals in space, but investigators performing such experiments in their Earth-bound laboratories.

The first long duration flight of a cell and tissue culturing device was placed in orbit in the Mir during FY 1996. This unit, a pathfinder for Space Station cell laboratories, has already grown three dimensional cartilage cell constructs larger than those attainable in terrestrial laboratories.

## Combustion Science

NASA awarded grants to three new investigators for spaceflight experimentation in microgravity combustion science. These involve the development of testing methodology and apparatus for categorizing the flammability of spacecraft materials in microgravity. the study of multi-component fuel droplets, and the study of so-called "cool flames," applicable to internal combustion engine performance. The definition of these experiments and subsequent peer reviews for approval for spaceflight will take place over the next few years.

Flown during the USMP-3 mission in February, 1996, three combustion investigations were performed in order to begin to directly address on-orbit safety of the crew from accidental fire. The Radiative Ignition and Transition to Spread Investigation and the Forced Flow Flame Spread Test studied the transition from a momentary ignition to a fire spread situation; from a scientific perspective these were highly successful as they identified new and unpredicted behavior. The third, Comparative Soot Diagnostics, provided the first test data on the in-space performance of the Shuttle's and the ISS smoke detection systems while determining particulate sizes and concentrations from typical spacecraft materials and a selected hydrocarbon fuel.

NASA will reach a major milestone on MSL-1 in March, 1997 in combustion science in microgravity with the on-orbit performance of many combustion experiments. These include one examining soot formation and oxidation (an area of critical importance to environmental and manufacturing concerns); another examining isolated fuel droplet combustion (an area of classical textbook interest and needed for improved modeling of engines and propulsion systems): and a third examining unique premixed hydrogen-oxygen-diluent burning (an area of long-standing scientific interest and to provide baseline data for hydrogen burning behavior).

## Fluid Physics and Transport Phenomena

The Critical Viscosity of Xenon (CVX) experiment will be conducted on STS-85 in July 1997. This is a fundamental physics experiment to determine the critical exponent for xenon more accurately than is possible under normal gravity. The CVX data will be used to quantitatively test the form for the crossover theory of critical viscosity and provide complementary results with the Zeno experiment to test the mode coupling theory of critical phenomena.

The Physics of Hard Spheres Experiment (PHASEI, being carried aboard the March 1997 MSL-1 mission, will examine order-disorder transitions in colloidal suspensions.

The first fight of the Extensional Rheology Experiment (ERE) will be conducted on a sounding rocket in late FY 1998. The science objectives are: 1) to generate a simple, homogeneous, shear-free flow in the material, to perform the first direct measurements of the extensional viscosity of a dilute polymer solution in uniaxial stretching flow during constant strain rate deformation and to characterize how this property varies with time and deformation rate; 2) to perform measurements of transient stress growth and relaxation of the test fluid: and, 3) to successfully isolate the mechanisms associated with elastic deformation and viscous hydrodynamics.

Science requirements are being established and the design of the test section hardware has begun for the Two-Phase Extended Evaluation in Microgravity (TEEM) experiment - a joint project between NASA JSC, LeRC and GSFC. The objective of this experiment is to provide extended duration microgravity data on two-phase systems necessary for risk mitigation for the International Space Station, in support of technologies for NASA's Enterprise for the Human Exploration and Development of Space. A launch opportunity for TEEM has not yet been established.

**Fundamental Physics**

The Critical Fluid Light Scattering Experiment/Zeno successfully completed its second flight on the USMP-3/STS-75 mission in February 1996. Zeno was a fundamental physics Experiment to extend and improve measurements of the decay rates and the correlation length of critical fluctuations in a simple fluid very near its liquid-vapor critical point. This second flight completed the flight experiment program of the Principal Investigator. The flight data are currently being analyzed.

**Materials Science**

The Isothermal Dendritic Growth Experiment (IDGE) is a fundamental microgravity materials science experiment that has been flown twice as part of the United States Microgravity Payload (USMP) series on the space shuttle Columbia. The first two flights of IDGE have provided the first ever set of convection-free dendritic growth data. Because virtually all industrially important alloys solidify from a molten state by a dendritic process, a fundamental understanding of dendritic solidification is necessary to correct mathematical models that provide the basis for improved industrial production techniques. In addition, during the February 1996 USMP-3 mission, the IDGE became the first U.S. microgravity experiment to be commanded and controlled from the Principal Investigator's university. Researchers and students from the Rensselaer Polytechnic Institute controlled the Isothermal Dendritic Growth Experiment (IDGE) through an electronic link to the NASA Lewis Research Center's Telescience Support Center. Remote telescience operations is a very cost effective tool that enables researchers to conduct microgravity experiments from their own facility, rather than traveling to a NASA operations center to conduct an experiment. This demonstration of telescience capabilities is especially important as this is the likely operations scenario for the coming International Space Station era. IDGE's third flight is scheduled for October 1997, aboard USMP-4.

The first flight of the Mechanics of Granular Materials (MGM) experiment was completed on the STS-79/Mir-4 mission in September 1996. The science objective is to obtain quantitative knowledge of the behavior of bulky granular materials under low confining pressures. The resultant data will be important in the understanding of soil mechanics and geotechnical engineering, earthquake engineering, coastal and off shore engineering, mining engineering, planetary geology, granular flow processes and engineering with granular materials. A second flight is scheduled for STS-86 in 1997 to complete the experiment data requirements matrix.

Three materials science experiments will be conducted on the MSL-1 mission in April, 1997: Coarsening in Solid-Liquid Mixtures (CSLM), Liquid Phase Sintering-2 (LPS-2), and Diffusion Processes in Molten Semiconductors (DPIMS). The objective of the CSLM is to study the coarsening kinetics of tin-rich particles in the eutectic liquids of lead-tin alloys of various compositions.

The second flight of the Bismuth-Tin Solidification Experiment (BiSn-2) on USMP-4 in October 1997 will provide data on the solidification behavior and the solid-liquid interface stability of bismuth and bismuth-tin alloys during crystal growth. It uses the Seebeck technique to measure interface undercooling temperature, resistance change across the sample to measure interfacial velocity, Peltier pulsing for demarcation of the sample interface, and quenching for chemistry and structure near the solid/liquid interface at temperature. The experiment is to be carried out in the French-developed MEPHISTO furnace.

**NASA/NIH Program**

The cell culture technologies and protein crystal growth research constitutes the major NASA/NIH emphasis for the next 5-6 years, but it is anticipated that other areas of cooperation will evolve from preliminary results. Over the past years, NASA has explored many aspects of the growth of protein crystals and the development of tissue culturing technologies which offer great promise. Similar types of efforts are being explored with several other institutes. This program will stimulate the joint agreements with other Federal agencies.

Two multidisciplinary research centers are supported: Massachusetts Institute of Technology, Cambridge and the Wistar Institute, Philadelphia. These Centers expand the pace of technology transfer in the biotechnology areas begun under the NASA-NIH inter-agency agreement. Through NASA-NIH cooperation, NASA has funded approximately 28 research proposals. It has also supported NIH-approved researchers in testing of tissue samples in NASA bioreactors at JSC. This has proven to be a very important undertaking in getting researchers to test NASA technology and in gaining acceptance in the larger biomedical community.

NASA is currently working with the National Eye Institute (NEI)to transfer NASA technology. This technology involves the use of laser light scattering to detect early signs of the onset of cataract formation. Discussions with the NEI have led to the decision to proceed with development of a prototype diagnostic tool. After successful demonstration, the NEI is interested in obtaining the technology for use in a large scale clinical trial.

NASA is also collaborating with the National Eye Institute using protein crystal growth technology to determine the structures of important proteins related to the signal pathway for sight. This is a joint program between NASA, NIH, and Eli Lilly.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE PRODUCT DEVELOPMENT

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Space Product Development..... | 26,500 | 13,000 | 12,900 |

## PROGRAM GOALS

Beginning in FY 1997, the Space Product Development activities previously budgeted within Space Access and Technology will be transferred to Life and Microgravity Sciences and Applications. The Space Processing budget has two program elements: the Space Product Development program and the Space Station Utilization program. The goal of the Space Product Development program is to facilitate the use of space for commercial products and services. These products and services can either be produced in space, or be the result of new approaches to ground-based commercial activities using insights gained from space flight. Consistent with this goal, the Space Product Development program seeks to increase U.S. business participation and investment in space-linked commercial goods and services in order to benefit U.S. industry and the economy as a whole. The program also seeks to provide the opportunity for students to engage with industry in space program activities.

As part of the establishment of the Lead Center management for the International Space Station at the Johnson Space Center, and the dissolution of the Office of Space Access and Technology, the LMSA program now includes management responsibility for these Space Product Development activities. Funding for the commercial and technology experiments planned for the International Space Station is now included under the Space Station research program, and discussed in that budget section.

## STRATEGY FOR ACHIEVING GOALS

The Space Product Development program is conducted in partnership with industry, universities, state governments and other Federal agencies. The program's purpose is to facilitate the use of space for commercial products and services. To accomplish this in-space commercial research and to develop industry partnerships, the program uses Commercial Space Centers (CSCs), specific project centers, and several NASA field Centers . The commercial centers are non-profit organizations, based at universities and NASA field Centers. The CSC's provide excellent opportunities to seek numerous and varied industrial affiliations. The Space Development program includes the following CSC's:

| | |
|---|---|
| Center for Bioserve Space Technologies | University of Colorado at Boulder |
| Center for Macromolecular Crystallography | University of Alabama at Birmingham |
| Consortium for Materials Development in Space | University of Alabama at Huntsville |
| Space Vacuum Epitaxy Center | University of Houston, Texas |

| | |
|---|---|
| Wisconsin Center for Space Automation and Robotics | University of Wisconsin at Madison |
| Center for Commercial Applications for Combustion in Space | Colorado School of Mines, Golden, CO. |
| Microgravity Automation Technology Center | Environmental Research Institute of Michigan, Ann Arbor, MI |
| Center for Space Power & Advanced Electronics (casting research) | Auburn University, Auburn, AL |
| Worcester Polytechnic Institute | Worcester, MA |
| Vanderbilt University | Nashville, TN |

The Space Product Development program provides the required access to NASA experiment facilities and offers access to space, utilizing the Shuttle mid-deck, SPACEHAB and Wake Shield facilities. Such access is prohibitively expensive for most corporations or small businesses, especially at the high-risk, exploratory stages. This barrier to access the commercial use of space has greatly inhibited the commercial development of space-linked products or services. Through the cost-sharing partnerships between NASA, the universities and industry offered by the Space Products Development program, private enterprises of all sizes are able to afford the research most important to the development of space-linked commercial products and services.

The Space Product Development Program has made significant progress in facilitating the commercial uses of space. As displayed in the metrics, nearly 200 commercial partners, invested over $40M in FY 1996 to use space to enhance their competitive position, develop new products and impact their "bottom line." In the process they create jobs, and contribute to "quality-of-life" improvements. This is consistent with the frequent access-to-space opportunities in FY 1995 and 1996. The decrease in these metrics is a result of reduced space research opportunities, as the Shuttle is being increasingly focused on the assembly of the International Space Station, with early Station utilization being rephased by changing Space Station requirements. The ability to retain, much less increase, commercial interest will become a significant challenge.

## MEASURES OF PERFORMANCE

The metrics for the Space Product Development area capture 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 Commercial Development Centers. The complete set of metrics also address patents, publications and commercial activity measures for Space Products.

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Industry Affiliates | 150 | 50 | 30 |
| University Affiliates | 60 | 50 | 20 |
| Payloads Flown | 24 | 5 | 2 |
| Non-NASA $M Leveraged | $40M | $40M | $30M |

| FY 1996 | Payload | Plan | Actual |
|---|---|---|---|
| STS-75/Columbia | Commercial Protein Crystal Growth (CPCG)-09 | February 1996 | February 1996 |
| STS-77/Endeavour | Spacehab-4 (10 payloads) | May 1996 | May 1996 |
| STS-79/Atlantis | Extreme Temperature Translating Furnace: Commercial Generic Bioprocessing Apparatus (CGBA) Materials in Devices as Superconductors; CPCG | August 1996 | September 1996 |

| FY 1997 | Payload | Plan/Revised | Actual |
|---|---|---|---|
| STS-80/Columbia | Wake Shield Facility-3 (WSF-3)/ CMIX-4 (commercial expmt) | November 1996 | November 1996 |
| STS-83/Columbia | Astroculture/Plant Generic Bioprocessing Apparatus | March 1997 | |
| STS-86/Atlantis | Liquid Phase Sintering/CGBA/CIBX (commercial experiment) | September 1997 | |

| FY 1998 | Payload | Plan |
|---|---|---|
| STS-89/Endeavour | X-ray Detector Test | January 1998 |

## ACCOMPLISHMENTS AND PLANS

In FY 1996, four CSC payloads flew on Shuttle missions: the Commercial Generic Bioprocessing Apparatus (CGBA) on STS-79, the Korund Liquid Phase Sintering metallurgy research, on STS-76 in March 1996; and the Materials in Devices as Superconductors and Commercial Protein Crystal Growth (PCG) projects, on STS-79 in September 1996. The CGBA will provide data for the agriculture industry to help improve certain plant characteristics, such as mechanical strength and nutrient content. The PCG is being flown to characterize additional proteins which will provide new design data for better drugs.

Flight hardware is being fabricated in FY 1996 to be used in KC-135 experiments for the Solidification Design/Thermal Properties Measurement program. These experiments will develop a thermal properties measurement capability on the Space Station for use in solidification design of castings.

The Phase I clinical trials of photo-kinetic therapy using a Light Emitting Diode (LED) light source to treat psoriasis will be concluded in FY 1996. Significant advances in treatment of breast melanoma and other tumors with LED technology and interactive drugs have also been achieved in FY 1996. The SPACEHAB-4 fight is expected to provide float zone single crystals of Gallium Arsenide and Gallium Antinomide for advanced electronic applications such as faster computer processing.

Conquest I launch took place April 3, 1996 as part of the Congressionally-mandated launch voucher demonstration.

In 1997 the zeolite industry will propose experiments designed to improve the catalytic value of zeolites, which in turn will increase the yield of certain petroleum products in petroleum refineries.

A multi-use, Space Station-based X-Ray diffraction facility has been defined and development will start in FY 1997. The facility will produce images of the internal structures of protein crystals grown on the Space Station, allowing rapid characterization and definition of the crystals. The capability to produce this imaging data in space and deliver that data to customers on Earth will be essential to optimize the Space Station's commercial protein crystallography operations, to provide timely data and to avoid loss of crystal degradation due to time delays.

The expanded double locker plant growth chamber will undergo key milestone reviews in FY 1997. The chamber is the product of a cooperative program between the Wisconsin Center for Space Automation and Robotics (at the University of Wisconsin in Madison) and Bioserve Space Technologies (at the University of Colorado in Boulder) and Kansas State University. It will be used for applied research exploring phenomena such as lignification of plants and gene splicing to produce superior plant stock for the agricultural industry.

Flight hardware will continue to be fabricated in FY 1997 for use in KC-135 experiments for the Solidification Design/Thermal Properties Measurement program.

The Space Product Development program plans to work with its centers and their industrial partners to capitalize on the results from initial experiments to complete planning for the commercial utilization of the Space Station. The intent is to focus resources on those applications and processes showing the greatest potential for commercial success.

Phase II clinical trials will be initiated for the Light Emitting Diode (LED) technology used for medical application to combat disease.

Cooperative research activity will be developed between the Consortium for Materials Development in Space and the commercial sector for transplantable cell tissue. If the Gas Permeable Polymer Materials (GPPM) flight results are positive, FDA clinical trials will be initiated for improved contact lenses. NASA technical analyses will be provided in support of the Critical Design Review for the plant growth chamber/Commercial Plant Growth Biotechnology Facility. Ground-based transition of plant growth facility for terrestrial use will also be pursued as will candidate drug spin-off of IMMUNE flight research. (The primary thrust of research focuses on immune system strengthening and countering bone loss. It is anticipated that specific drug therapies will emerge and be brought into the market place through this research.)

Significant work is planned in FY 1998 at all of the CSC's. Phase III clinical trials will continue for the LED technology in medical application. This will be the product development transition year. This work will be performed at the CSC/Wisconsin Center for Automation and Robotics.

Prototype completion is planned of the Plant Growth Biotechnology Facility at the CSC/Bioserve Space Technologies and Wisconsin Center for Automation and Robotics.

Market development of products in the magnetic bacteria immunoassay project, using results from flight data (CSC/Bioserve Space Technologies flight). Substantial effort is planned in the area of Mammalian Cell Stabilization, a process to inhibit cell

growth, that is a potential tool against cancer. The goal for this area for FY 1998 is commercial medical transition, based on flight results (CSC/Bioserve Space Technologies flight).

Industry, the Commercial Space Centers and NASA, will continue definition studies and commitment to future flight products. Twenty industrial commitments to the Combustion Center are targeted, using a defined path to Station utilization using as many LMSA developed facilities as practical. Space Station will be the "test bed" and technology platform for combustion activities once it is available for commercial utilization (CSC/Center for Commercial Applications of Combustion in Space).

Efforts will continue to bring to market those pharmaceuticals already engendered by previous space flight activity (CSC/Center for Macromolecular Crystallography flights).

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE SHUTTLE/SPACELAB MISSION MANAGEMENT AND INTEGRATION

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Space shuttle/spacelab mission management and integration ..... | 53,600 | 24,200 | 6,900 |

### PROGRAM GOALS

The goals of this program are twofold: (1) provide physical, analytical, and operations integration support 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.

### STRATEGY FOR ACHIEVING GOALS

In order to meet the program goals and objectives, NASA performs the mission planning, integration, and execution of all NASA Spacelab, Spacehab, the NASA/Mir Research Program (NMRP), and other attached Space Shuttle payloads to carry out a wide variety of space research. The program also supports the common small science payloads that use locker spaces in the Space Shuttle's lower crew compartment. Activities include system management and engineering development of flight support equipment and software; development of interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system: payload flight operations; and data dissemination to experimenters. Mission management activities are dependent upon the specific mix of missions in a particular year.

In addition, through this program, NASA 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 Space Shuttle/Spacelab 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 NMRP to the ISS program to achieve greater efficiencies.

### Center and Contractor Support

The principal NASA Centers which conduct activities in support of this program are the JSC, the KSC, and the MSFC. In FY 1998, JSC will provide the analytical integration and operations level project management support for the remaining two NMRP missions (NASA/Mir 8 and NASA/Mir 9, scheduled to be launched in the first and second quarters respectively), and the Neurolab mission (scheduled to be launched in the second quarter). MSFC will provide the analytical integration and operations level project

management support for the United States Microgravity Payload (USMP-4, to be launched in the first quarter. KSC will provide the physical hardware science payload integration project management support for the NASA science payloads on the Neurolab and USMP-4 flights.

In FY 1998, the primary contractors that will be supporting the program at the Centers are: Lockheed-Martin at JSC: the McDonnell Douglas Corporation's Payloads Ground Operations Contract (PGOC)at KSC: and Teledyne-Brown Engineering at MSFC. At JSC, Lockheed-Martin provides payload mission integration support for the missions managed by the JSC. At MSFC, Teledyne-Brown provides payload mission integration support for the missions managed by MSFC. At KSC, the primary PGOC functions include: processing flight hardware experiments for Spacelab and partial payloads, manifest scheduling and work control support, logistics support and sustaining engineering modifications to facilities and systems, and computational services for the Payload Operations Computer Network.

## MEASURES OF PERFORMANCE

The most significant measure of performance is the provision of an integrated system that ensures successful accomplishment of the science payload objectives. Although not directly responsible for the success of a particular experiment, the mission management organization is responsible 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 measured in terms of the number of primary missions and the number of middeck missions successfully flown as scheduled and the successful accomplishment of the science payload objectives:

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | Plan | Revised | Plan |
| Spacelab/Pallet Missions | 3 | 3 | 3 | 3 | 3 |
| Mir Missions | 3 | 3 | 3 | 3 | 2 |
| Middecks/Small Payloads | 8 | 8 | 5 | 8 | 12 |

USMI-2 Launch
Plan: 4th Qtr FY 1995
Actual: 1st Qtr FY 1996

The objectives of this Spacelab module mission were to conduct scientific and technological investigations in materials, fluids, combustion and biological processes and to explore potential applications of space for commercial products and processes. Fifteen investigations were baselined for this mission, as well as seven additional U.S. investigations conducted in the USML-2 Glovebox facility. This mission was successfully conducted in the first quarter of FY 1996, having been delayed due to Shuttle program considerations and weather problems.

| | |
|---|---|
| USMP-3 Launch<br>Plan: 2nd Qtr FY 1996<br>Actual: 2nd Qtr FY 1996 | This USMP-3 mission performed materials processing and other experiments in the microgravity space environment with in-flight monitoring of phenomena, sample production, and post-flight analysis of samples. Such activities are expected to significantly advance the basic knowledge of materials science and help develop better products and technology for use on Earth and in space. This mission was launched on schedule and was highly successful in the achievement of its scientific goals. |
| LMS Launch<br>Plan: 3rd Qtr FY 1996<br>Actual: 3rd Qtr FY 1996 | The LMS module mission performed scientific investigations in the fields of materials science, fluid physics, protein crystal growth, and biotechnology. Human and plant studies and a subset of investigations previously planned for SLS-3 were also conducted. This mission was launched on schedule and was highly successful in the achievement of its scientific goals. |
| ORFEUS-SPAS 2 Launch<br>Plan: 1st Qtr FY 1997<br>Actual: 1st Qtr FY 1997 | The second fight of the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer Shuttle Pallet Satellite (ORFEUS-SPAS-2) is an astronomical telescope for observations at very short wavelengths in two spectral ranges, the far ultraviolet (FUV) and the extreme ultraviolet (EUV). These spectrometers are mounted on the German built deployable/retrievable ASTRO-SPAS camer. |
| MSL-1 Launch<br>Plan: 2nd Qtr FY 1997 | The MSL- 1 will focus on microgravity combustion and international research in microgravity materials science. Three new microgravity combustion experiments will use two new, large research facilities constructed for this mission. |
| CRISTA-SPAS 2 Launch<br>Plan: 4th Qtr FY 1997 | The second flight of the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere Shuttle Pallet Satellite (CRISTA-SPAS-2)is a set of spectrometers which measures the constituents of Earth's middle atmosphere. These spectrometers are mounted on the German built deployable/retrievable ASTRO-SPAS camer. |
| USMP-4 Launch<br>Plan: 1st Qtr FY 1998 | This USMP-4 mission will perform materials processing and other experiments in the microgravity space environment with inflight monitoring of phenomena, sample production, and postflight analysis of samples. Such activities are expected to significantly advance the basic knowledge of materials science and help develop better products and technology for use on Earth and in space. |
| Neurolab Launch<br>Plan: 2nd Qtr FY 1998 | This mission will perform international research in brain function and behavior, including research on the autonomic nervous function, sleep regulation, vestibular physiology, developmental neurobiology, and sensorimotor function. |

| | |
|---|---|
| Alpha Magnetic Spectrometer Launch Plan: 3rd Qtr FY 1998 | This Department of Energy (DOE) sponsored AMS payload will fly twice, first on the Space Shuttle in 1998 and later on the International Space Station. AMS will search for cosmic sources of antimatter and missing matter (Co-manifested With NASA/Mir-9). |

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the Space Shuttle/Spacelab Mission Management and Integration program successfully managed three Shuttle missions: the second flight of the United States Microgravity Laboratory (USML-2), scheduled for flight during the last quarter of FY 1995, was delayed until the first quarter of FY 1996, due to Space Shuttle program considerations and inclement weather; the third flight of the United States Microgravity Payload (USMP-3) mission was scheduled and successfully accomplished during the second quarter: and the Life and Microgravity Sciences (LMS) mission was scheduled and successfully accomplished during the third quarter. In addition to the three Shuttle missions, the mission management organization supported the flights of 8 smaller middeck class science payloads sponsored both by NASA and other government agencies.

During FY 1997, the mission management organization will provide mission management support to the launch of the MSL-1 mission in addition to 3 flights to Mir (discussed within the Space Station program narrative.) The organization will also provide program coordination for the second flights of the Cryogenic Infrared Spectrometers and Telescopes for NASA the Atmosphere Shuttle Pallet Satellite (CRISTA-SPAS-2) and the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer Shuttle Pallet Satellite (ORFEUS-SPAS-2) missions, both scheduled for launch in FY 1997. In FY 1997, systems engineering efforts will continue to support methodologies for advocacy and coordination of U.S. research requirements-and implementation of processes and tools for mission planning for US payloads on future space platforms, primarily the phase II and III of the ISS. Space Station planning and integration efforts will intensify as the First Element Launch date of the ISS approaches (December 1997). Spacelab-related activities will be sharply reduced in FY 1997, because the Spacelab modules fly for the last time in early 1998.

During FY 1998, the mission management organization will provide mission management support to the launch of three Shuttle missions which will conduct Life and Microgravity scientific research: the fourth flight of USMP; the Neurolab mission: and the precursor flight of the Alpha Magnetic Spectrometer (co-manifested with NASA/Mir-9) along with two flights of the NMRP (NASA/Mir 8 and NASA/Mir 9). FY 1998 marks the conclusion of the very successful Spacelab program with the completion of the Neurolab mission.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### AEROSPACE MEDICINE AND OCCUPATIONAL HEALTH

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Aerospace Medicine and occupational health..... | 8,000 | 3,800 | 7,500 |

## PROGRAM GOALS

The goals of the Aerospace Medicine and Occupational Health programs are to: 1)provide for the health care and well-being of all NASA employees in their ground- and space-based work environments: 2) develop appropriate requirements for medical operations and medical research; and 3)promote applications of knowledge gained and technologies developed in the public and private sectors.

## STRATEGY FOR ACHIEVING GOALS

The primary objectives of the Aerospace Medicine and Occupational Health programs are to support the NASA Mission through the preservation and maintenance of the physical and mental health of Agency employees and the health and productivity of the astronauts, thus increasing the probability of success of space fight missions. The scope of work includes the refinement of standards and requirements for operational medicine in support of human space flight: provision of ground-based medical support for human space fight mission operations: and ensuring development of hardware, training, and protocols for maintaining clinical care readiness on-board spacecraft.

To achieve the program goals, several activities have been established, which are investments in technologies that will enable NASA to meet the challenges of space exploration in the new millennium. In addition, these technologies are being utilized today to enhance our abilities to provide medical care and medical education to NASA employees regardless of their location.

The Global Health Applications activity transfers NASA knowledge and technology achieved in aerospace medicine and occupational health to a variety of domestic and international endeavors that contribute to national competitiveness, education, and quality of life. This work is accomplished via publications and use of other media to inform others of our aerospace medicine and occupational health practices: promoting the incorporation of these practices in educational curricula: and transferring the technologies developed for medical care of space flight crews to terrestrial health care applications such as the use of telemedicine to improve the access to health care in rural and underserved areas and to support medical responses to disaster-stricken areas both in the U.S. and abroad.

The Occupational Health program establishes policies and manages implementation of NASA-wide occupational and environmental health programs and services through the Agency Occupational Health Office located at the Kennedy Space Center.

These services include provision of immediate medical care for acute illnesses, accidents and injuries in the workplace; controlling and responding to acute and chronic exposure of employees to toxic materials, hazardous environments and harmful physical agents in the workplace: implementing state-of-the-art wellness programs and preventive medicine programs based on professional practice guidelines of the American College of Occupational and Environmental Medicine.

The JSC has established and is operating a telemedicine system at Star City, Russia to support the U.S. astronauts, flight surgeons, and other personnel in Russia supporting Phase I of the International Space Station (ISS) Program. In addition, JSC is developing a portable telemedicine capability, which will support medical operations activities for the ISS.

Collaborative initiatives with other agencies, academia, and industry will be established to leverage existing technologies and foster development of emerging technologies in telecommunications and information systems as they apply to health care in space flight.

**Center and Contractor Support.**

The JSC and Headquarters are the principal Centers involved in the Aerospace Medicine program. The KSC and Headquarters are the principal Centers involved in the Occupational Health Program. JSC will be assigned Lead Center responsibility for the Aerospace Medicine program, which will be renamed the Space Medicine program. The ARC and LeRC are key Centers in the development of communications and computer technologies for the support of NASA's Spacebridge to Russia, an Internet based telemedicine testbed. The JSC will manage telemedicine efforts in support of medical operations activities for the Human Space Flight Program. The KSC serves as the lead center for management and implementation of occupational and environmental health programs. The ARC serves as the lead center for the telecommunications via the NASA Science Internet. Wright State University School of Medicine and the Texas Medical Center are the major contractors for the Aerospace Medicine program.

**MEASURES OF PERFORMANCE**

| | |
|---|---|
| Multilateral Medical Policy Board<br>Plan: 4th Qtr FY 1997<br>Actual: Under review | Establish a document for the Multilateral Medical Policy Board which validates medical requirements, standards, protocols, and flight rules for all the International Space Station Program. |
| Executive Council for Health, Environmental Management and Safety<br>Plan: 2nd Qtr, FY 1997<br>Actual: Under review | Establish a council for the Agency to ensure Agency-wide uniformity of programs and compliance with externally-mandated laws and regulations. |

| | |
|---|---|
| Commercial Space Center for Informatics and Medical Technologies<br>Plan: 2nd Qtr, FY 1997<br>Actual: Under review | Establish a Commercial Space Center for Informatics and Medical Technologies at a leading academic institution to develop partnerships and leverage resources and technologies in the fields of telemedicine, information technologies, and medical technologies. |

The Aerospace Medicine and Occupational Health program is in the process of redefining criteria for measuring performance. Possible criteria include: the conveyance of technology, protocols and procedures for terrestrial applications: and overall fitness of humans in space and their ability to do productive work by measuring the effectiveness of medical systems, countermeasures, and standards. Possible Occupational Health criteria include documentation of the number of controls instituted for chronic exposures to tcxic and or physical and biological hazards, the number of occupational medicine exam abnormalities, the number of life-threatening health risk factors identified and controlled in the employee population, and the number of OWCP claims filed and controverted.

**ACCOMPLISHMENTS AND PLANS**

The JSC-developed portable telemedicine instrumentation pack (TIP)has been evaluated in several settings, including the Harris County Jail and between the Crow Indian Reservation in Montana and a hospital in Billings, MT. The TIP is currently being integrated with a computer and will be flown on the Space Shuttle in late FY 1997 for testing (planned STS-87). The Space Biomedical Center for Training and Research at Moscow State University (MSU) completed its first year of activities with highlights in several disciplines, including aerospace medicine, telemedicine and medical education.

The Internet-based telemedicine testbed called Spacebridge to Russia, which links several medical centers in the U.S. with several clinical sites in Moscow and integrates Internet tools such as the World Wide Web and video teleconferencing capability to support medical consultations and medical education, were continued. Medical lectures have been exchanged between Baylor College of Medicine and MSU using the Internet.

A space medicine project which focuses on continuous improvement in medical requirements for spaceflight through the development of appropriate laboratory and diagnostic tests, was continued. This project incorporates activities from several JSC programs including the Crew Health Care System for ISS, medical operations activities, and the Human Research Facility. Two space medicine program activities, Spacebridge to Russia and the Global Health Network, were recognized for achievements in the field of Internet applications. They were both named as finalists of the 1996 National Information Infrastructure (NII) Awards.

The Aerospace Medicine program led a Agency-wide initiative to develop a strategic plan on telemedicine. In addition, a comprehensive inventory of NASA telemedicine activities was developed.

FY 1997 plans for the Aerospace Medicine Program include: 1) continuing the Internet-based telemedicine testbed, Spacebridge to Russia: 2) supporting development of the Pan American Health Organization and Global Health Network Internet systems for

disaster response planning and for sharing preventive medicine and public health information; 3) developing a network of medical experts for all telemedical consultations for space flight mission support (e.g., flight crew or disaster recovery): 4) developing and in-flight testing of the TIP: 5) continuing comprehensive risk assessment and review of medical requirements for space flight during long duration missions: 6) continuing the Space Medicine Project for the development of medical requirements for research in order to ensure the timely availability of adequate procedures, protocols and countermeasures to maintain and enhance human health and performance during extended duration missions: 7) providing support for operational medical activities for Space Shuttle missions, Phase 1 of the ISS, and the implementation of a comprehensive medical care facility for the ISS; 8) establishing a Joint Medical Policy Board and developing joint medical operations requirements documents with all the ISS partners: 9) continuing the efforts of the Space Biomedical Center: 10) establish a Commercial Space Center (CSC) for Informatics and Medical Technologies: 11) invest in collaborative activities with academia, other agencies, and industry in the application of emerging technologies in communications and information systems to health care: and 12) work closely with medical representatives of the ISS partners in developing medical care requirements, standards, and addressing medical issues.

FY 1997 Plans for the Occupational Health Program include: 1) establishing an Occupational Health Executive Council with a Health, Environmental Management, and Safety subcommittee to ensure Agency-wide uniformity of programs and compliance with externally mandated laws and regulations: 2) expansion and implementation of an Agency-wide Material Safety Data Sheet (MSDS) system for the cataloging and tracking of toxic, chemical and hazardous substances; 3) development of an Asbestos surveillance system; 4) development of a Lead surveillance system: 5) implementation of an Agency-wide workers' compensation case tracking system for reduction of Agency compensation costs: and 6) development of manpower guidelines for the population supported, exposures, and regulatory requirements.

FY 1998 plans are to continue to provide support to operational medicine activities for the Space Shuttle and NASA/Mir missions and to conduct medical requirements reviews in preparation for the ISS era. It will continue to evaluate new technologies that will support these activities, and ensure appropriate systems are in place to enhance mission success. Activities at the SBC will continue. Support of the Aerospace Medicine Project will continue to ensure the development of medical requirements and assessment of medical risks, establishment of priorities for medical research, and development of medical flight policies in support of all U.S. spaceflight programs including Shuttle, NASA/Mir, the ISS, and future exploration missions. Activities of the CSC for Informatics and Medical Technologies will continue. Efforts with the Multilateral Medical Policy Board and Multilateral Medical Operations Working Group will continue. Investments in collaborative activities with academia, other agencies, and industry in the application of emerging technologies in communications and information systems to health care for space flight will continue.

FY 1998 plans for the Occupational Health Program include: 1) the continued operation of the Occupational Health Executive Council with a Health, Environmental Management, and Safety subcommittee to ensure Agency-wide uniformity of programs and compliance with externally mandated laws and regulations; 2) updating and coordination of an Agency-wide Material Safety Data Sheet (MSDS) system for the cataloging and tracking of toxic, chemical and hazardous substances: 3) monitoring of an Asbestos surveillance system; 4) monitoring of a Lead surveillance system: 5) oversight of an Agency-wide workers' compensation case tracking system for reduction of Agency compensation costs; and 6) phased implementation of manpower guidelines for the population supported, exposures, and regulatory requirements.

Mission to
Planet Earth

SCIENCE. AERONAUTICS. AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

OFFICE OF MISSION TO PLANET EARTH

MISSION TO PLANET EARTH

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Earth observing system | 554,200 | 586.700 | 679.700 | SAT 3-6 |
| Earth observing system data information system | 247.200 | 254.600 | 244.700 | SAT 3-22 |
| Earth probes | 80.100 | 57.200 | 40.700 | SAT 3-26 |
| Applied research and data analysis | 350.100 | 373.400 | 325.300 | SAT 3-32 |
| Global observations to benefit the environment | 5.100 | 5.000 | 5.000 | SAT3-45 |
| Launch services | 107.100 | 84.700 | 121.900 | SAT 3-47 |
| Construction of facilities | 17.000 | --- | --- | SAT 3-49 |
| (Earth system science building) | (17.000) | (---) | (---) | |
| Total | 1,360.800 | 1,361.600 | 1.417.300 | |

Distribution of Program Amount by Installation

| | | | |
|---|---|---|---|
| Johnson Space Center | 100 | --- | --- |
| Kennedy Space Center | 4.900 | 4.700 | 6,600 |
| Marshall Space Flight Center | 4.200 | 5.400 | 4.000 |
| Stennis Space Center | 17.200 | 66.200 | 16.200 |
| Ames Research Center | 38.100 | 8.200 | 5.500 |
| Dryden Flight Research Center | 5.100 | 19.000 | 18.700 |
| Langley Research Center | 27.000 | 42.500 | 30.600 |
| Lewis Research Center | 68.400 | 16.300 | 36.000 |
| Goddard Space Flight Center | 922.400 | 991,300 | 1.067.600 |
| Jet Propulsion Laboratory | 68.600 | 97.200 | 103.100 |
| Headquarters | 204.800 | 110.800 | 129.000 |
| Total | 1,360.800 | 1.361.600 | 1.417.300 |

## OFFICE OF MISSION 1 PLANET EARTH

### PROGRAM GOALS

The purpose of NASA's Mission to Planet Earth (MTPE) Enterprise is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. MTPE is pioneering the new interdisciplinary field of research called Earth system science, born of the recognition that the Earth's land surface, oceans, atmosphere, ice sheets and biota are both dynamic and highly interactive. It is an area of research with immense benefits 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 global research community, MTPE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. MTPE has established three broad goals: 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 MTPE science and technology in the public and private sectors.

### STRATEGY FOR ACHIEVING GOALS

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. MTPE 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 programs to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state and local government tap this knowledge to produce products and services essential to achieving sustainable development. MTPE is NASA's contribution to the U.S. Global Change Research Program (USGCRP).an interagency effort to understand the processes and patterns of global change.

The Earth Observing System (EOS),the centerpiece of MTPE, is a program of multiple spacecraft (the *AM,* PM, Chemistry series, Landsat-7, and others) and interdisciplinary science investigations to provide a 15 year data set of key parameters needed to understand global climate change. The first EOS satellite launches begin in 1998. Preceding EOS are a number of individual satellite and Shuttle-based missions which 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) instrument, launched in 1978 and 1991, measures 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. The French and U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992. to study ocean topography and circulation. The NASA Scatterometer (NSCAT),also launched on the Japanese ADEOS in 1996, maps ocean

winds, In 1997 the Tropical Rainfall Measuring Mission (TRMM) will measure tropical precipitation. Complementing EOS will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and make innovative measurements in parallel with the 15 year mission of EOS. The first ESSP mission should be ready for launch in 2000.

Data from MTPE missions, both current and future, are captured, processed into useful data products, and broadly distributed by the EOS Data and Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions will remain available in active archives for use by current and future scientists. Since these data are useful beyond the Earth system science research community, EOSDIS will 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, MTPE 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.

The intellectual capital for these missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. MTPE's research and analysis program funds over 1,700 researchers from nearly every U.S. state. There are also scientists from seventeen other nations, funded by their own countries but, collaborating with U.S. researchers. These researchers develop Earth system models from MTPE data, conduct laboratory experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our home planet. MTPE-funded scientists are recognized as world leaders in their fields, as exemplified by the awarding of the 1995 Nobel Prize in chemistry to two who identified the threat of cholorflorocarbons to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs which enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

In 1996, the first MTPE Science Research Plan was published. The plan lays out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use change; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; long-term climate natural variability and change research: and atmospheric ozone research. The plan also outlines some twenty related areas of research which round out the MTPE contribution to Earth system science.

The challenges of Earth system science, sustainable development, and protection of people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international players. As mentioned above, the USGCRP coordinates research among thirteen U.S. government agencies. MTPE has extensive collaborations with the National Oceanic and Atmospheric Administration (NOAA) on seasonal-to-interannual climate prediction. MTPE is the responsible agent in NASA for managing the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DOD) are collaborating on a convergence of the civilian and military weather systems. MTPE collaborates with the U.S. Geological Survey (USGS) on a range of land surface, solid Earth and hydrology research. NASA, NOAA 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 digital terrain data on most of the Earth's surface. MTPE participates in the World Climate Research Program, the

International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization. Most of MTPE's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch vehicles.

MTPE has adopted an evolutionary approach to fulfilling its mission and goals. During 1995, NASA conducted a comprehensive review of the entire MTPE Enterprise. The goal was to enable: a focus on near-term science and associated applications: explicit provision for new technology infusion: reduction in life-cycle cost of the EOS program; provision of new science opportunities through smaller, quicker and less expensive missions (the genesis of ESSP); and closer participation with other Federal agencies (especially NOAA), commercial firms and international partners. The result of this review is an EOS which is lower in life-cycle cost, more flexible in implementation, and of greater utility to the science community and more adaptable to commercial opportunities. Out of this review came planning for MTPE involvement in the new millennium program which conducts the development and flight demonstration of advanced, smaller instruments for the EOS second series. Our basic approach has been endorsed by the National Research Council (NRC) through its Board on Sustainable Development.

We continue to refine this plan and seek the advice of the NRC and other external groups as we progress. In 1997, NASA will conduct the first biennial review of MTPE. The biennial review will examine all aspects of MTPE with a view toward incorporating new scientific understanding, technology development, and expanded collaborations with national and international operational and research satellite systems. The product of the biennial review will be reviewed by an NRC-organized panel of external experts, and will be the basis for MTPE's FY 1999 budget request development.

This budget fully supports the baseline program presented in the FY 1997 budget. The requested funding provides for a robust science program. MTPE has developed an integrated science plan that relates research plans to space observations, and fully integrates EOS and non-EOS science. The basic themes of this plan are consistent with the USGCFW and contain five areas of emphasis. Three initiatives which will further contribute to a robust science program as well as to technology infusion have been incorporated. These initiatives include an Uncrewed Aerial Vehicle (UAV) scientific research program, an instrument incubator, and an advanced geostationary study.

The UAV-based research program will focus on making in *situ* atmospheric measurements in the tropopause and lower stratosphere. UAV's will measure detailed temporal changes by staying over a target area for an extended period, providing unique views of cloud structure and calibration and verification of MTPE's satellite instrumentation. These UAV-based measurement strategies are based on emerging technology which should increase scientific return at a reduced cost to the government.

The instrument incubator is a technical and managerial approach for enabling rapid deployment of new, less costly, and less resource-intensive (i.e., less power, weight, volume, etc.) scientific instruments. It will focus on ground-based development and testing of instrument system and subsystem technologies by applying the results of the core technology (funded in space science) program to MITE-specific requirements.

The advanced geostationery study provides for concept studies of the application of the latest technology to the development of small, compact, geostationary satellites that will support research and technology objectives. Data from advanced geostationary studies will be used for both global climate change and research missions.

These initiatives will be funded out of the savings realized elsewhere in the MTPE program, including the common spacecraft procurement. In addition to these savings, MTPE is committed to continue to look for ways to reduce near-term funding requirements. The Chemistry-1, Laser Altimetry, and AM-2 missions are all under study to determine if cost savings can be achieved through the use of new approaches to these missions such as the utilization of smaller spacecraft.

Two significant changes in the management approach to MTPE were implemented in 1996. The MTPE program office, at the Goddard Space Flight Center (GSFC),assumed a larger role when program management responsibilities migrated from NASA Headquarters to GSFC. Further, the NASA Office of Space Access and Technology was disestablished with advanced technology development to be managed by the enterprises and coordinated by a chief technologist in the Office of the Administrator. With this change, MTPE assumed responsibility for the small spacecraft technology initiative (Lewis & Clark) and the commercial remote sensing program.

Upcoming activities over the next two years in the MTPE program include, in the Earth probes program, launch of the Tropical Rainfall Measuring Mission (TRMM) in late 1997. The Lewis and Clark land imaging spacecraft, developed in partnership with commercial firms, will be launched in 1997. The MTPE mission operations program will begin operations and data processing of the TRMM as well as activities for currently orbiting satellites, including TOPEX/Poseidon, UARS, NSCAT and TOMS. The experiments of opportunity program will be focused on Shuttle Imaging Radar-C (SIR-C) and launch the Measurement of Air Pollution from Satellites (Maps) on MIR, a cooperative commercial venture. Within the EOS, a preliminary design review will be held for PM-1 in 1997. Instruments for AM-1 and Landsat-7 will be delivered in 1997. The EOSDIS will release Version 1 in 1997, and prepare for the release of Version 2.

The EOS AM-1 will be launched in June 1998. This mission will provide key measurements that will significantly contribute to our understanding of the total Earth system. The AM-1 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 will be launched no later than December 1998. Landsat-7 will carry a single instrument, the enhanced thematic mapper plus, which will make high spatial resolution measurements of land surface and surrounding coastal regions. This mission will provide data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, national security and other civil and commercial purposes.

The measurements to be made by these and other future MTPE missions as well as current on-orbit missions provide data products that are used extensively in the MTPE science program. The program encompasses over 1,700 scientific activities at universities, research laboratories, and government research organizations. 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 1998 FUNI REQUIREMENT

### EARTH OBSERVING SYSTEM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| AM series | 178,700 | 82,800 | 49,100 |
| PM series | 103,700 | 149,700 | 218,000 |
| Chemistry.. | 27,300 | 63,300 | 100,600 |
| Special spacecraft.. | 60,500 | 83,100 | 91,700 |
| Landsat-7 | 85,200 | 76,200 | 52,100 |
| Algorithm development | 73,300 | 84,900 | 102,700 |
| Technology infusion | 25,500 | 46,700 | 65,500 |
| (New millennium program) | (20,000) | (35,000) | (40,000) |
| (Sensor & detector technology) | (5,500) | (4,700) | (5,500) |
| (Instrument incubator) | (--) | (7,000) | (20,000) |
| Total., | 554,200 | 586,700 | 679,700 |

## 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: (1) to 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) to develop a comprehensive data and information system, including a data retrieval and processing system: (3) to serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make MTPE data and information publicly available: and, (4) to 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 be integrated with 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 change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM), afternoon (PM), and Chemistry series. Beginning in 1998, 2000, and 2002 respectively, the first satellite in each series will be flown for a period of six years in order to obtain, at a minimum, a data set that will span fifteen years. Additional observations will be provided by the Landsat-7 mission beginning in 1998. Data continuity for the Landsat program will be maintained by flying an advanced technology Landsat-like instrument on the AM-2 mission in 2004.

International participation is a highly valued element of the EOS program. Understanding global climate requires a global effort. In addition to the fiscal benefits from integrating our complimentary science programs, it is critical to ensure that the world's decision makers have a common body of information that is credible and well understood. AM-1 includes instruments provided by Canada and Japan. International partners contribute to several other key EOS missions. Within the special spacecraft program, flights of the Radar Altimetry and Laser Altimetry satellites, as well as Stratospheric Gas and Aerosol Experiment-III (SAGE-III), SeaWinds, Active Cavity Radiometer Irradiance Monitor (ACRIM), Solar Stellar Irradiance Comparison Experiment (SOLSTICE), and Clouds and Earth's Radiant Energy System (CERES) instruments will be accomplished with a combination of domestic dedicated spacecraft and international participation by Japan, Russia, France, and potentially other countries.

EOS program planning began in 1983 with the definition of the science and mission requirements by the EOS Science and Mission Requirements Working Group (SMRWG). The SMRWG charter was to examine the major Earth science questions for the 1990's and to define the requirements for low-Earth-orbit observations needed to answer these questions on a comprehensive multi-disciplinary basis. The SMRWG's report, issued in 1984, listed five basic recommendations concerning Earth science in the 1990's:

- A program must be initiated to ensure that the present time series of Earth science data are maintained and continued. Collection of new data sets should be initiated.
- A data system that provides easy, integrated, and complete access to past, present, and future data must be developed as soon as possible.
- A long-term research effort must be sustained to study and understand these time series of Earth observations.
- The EOS program should establish an information system to carry out those aspects of the recommendations that go beyond existing and planned activities.
- The scientific direction of EOS should be established and continued through an International Scientific Steering Committee.

The Earth System Sciences Advisory Committee (ESSAC) was appointed in November 1983 by the NASA Advisory Council to consider directions for NASA's Earth sciences program. The committee's report, issued in May 1986, recognized EOS as the centerpiece of the future Earth sciences implementation strategy. It stated the following goal of Earth system science: "To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve on all time scales." It also identified the following challenge to Earth system science: "To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity."

The successor to the SMRWG, the EOS Science Steering Committee (SSC), continued the definition of the EOS program and provided an overall implementation strategy in its report issued in 1987. Concurrent with the SSC work, NASA included the EOS program under a broader Agency initiative termed MTPE, which included other efforts such as the Earth probe missions and NASA's participation in the International Geosphere Biosphere Program (IGBP) and the World Climate Research Program (WCRP). By proceeding to carry out the recommendations of the SMRWG and the ESSC, including EOS, the SSC argued that it would be possible to move from a single-discipline research mission to a comprehensive mission addressing all aspects of the Earth as a system. Thus, the concept of an Earth system was adopted as the EOS scientific thrust.

An announcement of opportunity (AO) to solicit proposals for EOS investigations was issued in January 1988. The EOS program objectives were based on the requirements and goals of the SMRWG, SSC, and ESSAC. In responding to the AO, proposers could offer to do interdisciplinary studies to carry out integrated Earth system research leading to the development of comprehensive Earth system models, to be members of research facility teams (formed to provide scientific guidance for the development of the research Facility Instruments (FI) and to analyze and interpret data from them), or to be Principal Investigators (PI) of proposed instruments and data products. The EOS selection process was completed in February 1989, with the selection of six team leaders and 93 team members for the six NASA research FI's, 24 instrument PI's, and 29 interdisciplinary team PI leaders to participate in the definition phase of the EOS program.

The EOS Investigators Working Group (IWG), formed in 1989, consists of PI's (instrument and interdisciplinary), and team leaders to provide scientific advice and guidance for the program. The program scientist (from NASA Headquarters) and the senior project scientist (from GSFC) co-chair the IWG. The working bodies of the IWG include twelve science panels. The chairpersons of each of these panels, together with the program scientist and senior project scientist, constitute the Science Executive Committee (SEC) of the IWG. Membership on the panels is generally open to all EOS investigators, including co-investigators on any EOS investigation and members of EOS FI teams. Scientists outside the group of EOS investigators are also included in the various panels.

The IWG plays a leading role in defining the overall science thrust for the EOS program. It coordinates the research efforts and provides guidance and advice to the EOS program and project, as appropriate, concerning all major scientific issues. It will meet regularly throughout the lifetime of the program.

The EOS study project was established at GSFC in 1983. During the Phase A and B study periods, GSFC and the Jet Propulsion Laboratory (JPL) performed mission, data system and spacecraft studies resulting in a conceptual design of a dual series of

spacecraft missions that would satisfy the EOS requirements. The spacecraft were designated EOS-A and EOS-B, with GSFC and JPL having the respective managerial responsibilities. Following the EOS Non-Advocacy Review (NAR),held in June 1989, management responsibilities for the EOS-B series, as well as the project management role for the execution phase of EOS, were transitioned to GSFC. The synthetic aperture radar (SAR), which was an FI to be launched on EOS-B. was identified as an independent mission, to be managed by JPL, and a candidate for separate program approval. In 1990, responsibility for development of the platform was transferred from the space station program to EOS. EOS management became centralized within the EOS project at GSFC.

The EOS program was approved by Congress as an FY 1991 budget initiative. The payload for the first flight (EOS-A1) was selected in January 1991, following conceptual design and cost reviews of the selected instruments and IWG Payload Panel recommendations on scientific priorities and synergism. The baseline flight segment consisted of two series of large observatories, EOS-A and-B, in 1:30 PM ascending, sun-synchronous orbit, launched by a Titan-IV with solid rocket motor upgrades from the Western Space and Missile Center (WSMC). Each observatory had a five-year life and each was to be replaced twice to provide a 15-year mission. The budget runout through FY 2000 was $17 billion.

The NRC advises the federal government through reports of reviews it conducts using its various committees, which involve the broad community of science and technology experts. Prior to the EOS new start approval in FY 1991, their report, "The U.S. Global Change Research Program: *An* Assessment of FY 1991 Plans," provided a critical review of the EOS program.

In the July 1991, report, "Assessment of Satellite Earth Observation Programs 1991," the NRC was in general agreement with the EOS plan for the large EOS-A observatory and its selected payloads. It expressed concern that the total EOS budget size could lead to potential delays, noted data gaps in key areas, and endorsed the MTPE Earth probe concept. These reviews were the beginning of a series of reviews and evaluations of the program to ensure the proper scientific return on the EOS investment.

*As* part of the FY 1992 budget process, the Committees on Appropriations directed NASA to restructure the EOS program to:

- Focus the science objectives of EOS on the most important problem of global change (i.e., global climate change).
- Increase the resilience and flexibility of EOS by flying the instruments on multiple, smaller platforms rather than a series of large platforms.
- Reduce the cost of EOS through FY 2000 to $11 billion.

In the summer and fall of 1991, NASA conducted a restructuring of the program to meet the Congressional mandate. This process included an independent review by the External Engineering Review Committee, which issued its report in September 1991. The process also involved assessment by the scientists who will use the data from EOS, including both the EOS IWG and the EOS Payload Advisory Panel, The EOS project at GSFC conducted studies to determine how the EOS instruments could most effectively be configured on small spacecraft. In December 1991, the NASA Administrator reviewed and approved the restructured EOS program, and in March 1992. NASA submitted its report on the restructured program to Congress. Congress approved the restructured program in 1992.

Recognizing that the subsequent budget environment would not support the complete and timely implementation of the restructured EOS program described in the March 1992, report to Congress, the NASA Administrator directed that the program be rescoped with a goal of further reducing its costs through FY 2000 by 30% to $8 billion. The EOS rescope was completed in June 1992. satisfying the 30% reduction by capitalizing on efficiencies, reducing at-launch science data products, by rephasing work, by increasing international participation, and by deleting the High-Resolution Imaging Spectrometer (HIRIS) flight instrument. As a result of the rescoping process, EOS became recognized by NASA as a cost-driven program.

In the 1995 Congressional budget cycle, the EOS budget was reduced by $758.5 million through FY 2000, to $7,243.4 million, of which $131.3 million was due to a funding responsibility transfer. The EOS rebaselining effort conducted in 1994, with the following results, was reflected in the FY 1996 budget submission.

- Preserve the scientific integrity of EOS and MTPE
- Preserve the measurement complement of the first mission in each series
- Preserve the launch dates for AM-1, PM-1 and Chemistry-1
- Phase EOSDIS development to support missions through FY 2000
- Restore reserves to a prudent level
- Incorporate appropriate technology advancements
- Fit within annual funding guidelines for the EOS program
- Replace major spacecraft at six year intervals

Public Law 102-555 returned the development, operations and data distribution of the Landsat-7 program to the federal government in 1992. It established the Landsat Program Management (LPM)team comprised of the DOD and NASA. DOD was responsible for the acquisition of the satellite and NASA was responsible for the development of the ground system. In the fall of 1993, DOD withdrew from the program. At the direction of the National Science and Technology Council (NSTC), the Office of Science and Technology (OSTP)initiated a review and restructuring of the Landsat-7 program. Under Presidential Decision Directive (PDD)/NSTC-3, the Land Remote Sensing Strategy was established. This strategy implemented a program management structure for the Landsat-7 program, which made NASA responsible for development of the satellite, instrument and ground system, USGCW responsible for operations, and the USGS, in conjunction with the EOSDIS Land Process Distributed Active Archive Center (LPDAAC),responsible for data archive and distribution. During the EOS rebaselining process, the Landsat-7 program was integrated with EOS. As another aspect of the rebaselining, the EOS science program was reorganized. The funding to support the activities of the EOS instrument investigators and interdisciplinary science investigators was moved to research and analysis. The science algorithm development and maintenance remains in the EOS budget.

During 1995, NASA conducted a comprehensive review of EOS to reshape mission planning to accomplish a number of interrelated objectives: substantially reduce EOS life-cycle costs while preserving the basic measurement set: provide now for technology infusion so that it will be available in time to be able to lower the cost of the second and third EOS series: provide new science opportunities through small satellites: and, adjust program management to an evolutionary approach.

This "reshaping" exercise recognized that the first series already employs or advances the state-of-the-art in spacecraft and instruments. Even so, savings achieved in the EOS Data and Information System (EOSDIS) implementation and other changes enable some savings and improvements in the first series. These include accelerating Laser Altimetry and ACFUM by one year, providing a spacecraft for SOLSTICE (previously awaiting a flight of opportunity), and the explicit provision of funding within the EOS budget for new technology missions.

The second series relies upon technology development to reduce the sue of instruments, and therefore, the size of the spacecraft required--cutting the total weight approximately in half for the multi-instrument missions. This should enable movement from Medium Class Expendable Launch Vehicles (MELV's) in the first series to Medium-Light Class ELV's (MLELV's) in the second series, when we expect these launch capabilities to be available. One key to the development of these advanced instruments is NASA's new millennium program, in which NASA's programs for MTPE and Space Science are engaged in demonstration flights of much smaller prototype component technologies.

The reshaped second series also provides for an advanced Landsat-type instrument to be incorporated on EOS AM-2, saving the government the cost of a separate spacecraft and launch (approximately $325 million in the Landsat-7 program). The EOS PM-2 spacecraft can be substantially downsized if the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) can incorporate an infrared sounder with adequate specifications and calibration. The first NPOESS satellite will be ready for launch in 2007 with a probable launch date of 2009. NASA will work with NOAA and the DOD through the NPOESS Integrated Program Office (IPO) over the next three years to find common requirements in sounding as well as other areas. Downsizing the remaining EOS PM-2 instruments enables them to be flown on a small spacecraft. The second EOS Chemistry mission is planned to be split into two smaller missions: one for largely stratospheric measurements taken in a monitoring mode and one largely for tropospheric measurements taken in a process study mode. Autonomous operations will be adopted in the second series to further reduce the cost of ground operations.

The third EOS series is left relatively undefined to allow maximum flexibility to accommodate emerging science requirements, technology infusion, and greater international and commercial participation to reduce the cost of completing the basic commitment to the EOS measurement set. By this point in the development program, the process for infusion of new technology from the new millennium program and other sources will be routine. Further advances in computing and network technology should continue to decrease EOSDIS operations costs.

### AM Series

The global climate change research emphasized by the *AM* instrument data set will include cloud physics, atmospheric radiation properties, and terrestrial and oceanic characteristics. Because the *AM* series primarily observes terrestrial surface features, a morning equatorial crossing time is preferred to minimize cloud cover over land. The primary contractors associated with the program are Lockheed Martin Missiles and Space (LMMS) for the *AM-*1 spacecraft, Hughes Santa Barbara Remote Sensing (SBRS) for the Moderate Resolution Imaging Spectrometer (MODIS) instrument, TRW for the CERES instrument (the instrument will also be flown on the TRMM in 1997 and PM series spacecraft, and as a flight of opportunity), and Lockheed Martin Commercial Launch Services for the *AM-*1 Atlas Centaur/IIAS launch service. The Multi-Angle Imaging Spectro-Radiometer (MISR) instrument is being

built in-house at JPL. The Japanese will provide the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument and the Canadians will provide the Measurement of Pollution in the Troposphere (MOPITT) instrument for the ***AM-1*** spacecraft.

## PM series

The research focus of the PM series 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 program are TRW for the common spacecraft to be used for PM-1 and Chemistry-1: Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS)instrument: and Aerojet General Corporation for the Advanced Microwave Sounding Unit (AMSU) instrument. Japan will provide the Advanced Microwave Scanner Radiation (AMSR) instrument for the PM-1 spacecraft and Brazil will provide a microwave instrument, the Humidity Sounder from Brazil (HSB).

## Chemistry Series

The study area for the Chemistry series will be atmospheric chemical species and their transformations. The Tropospheric Emission Spectrometer (TES) and the Microwave Limb Sounder (MLS)instruments are planned to be built in-house at JPL. The Japanese will provide the Ozone Dynamics Ultraviolet Spectrometer (ODUS)instrument and the University of Colorado and Rutherford Appleton Lab/Oxford University in the United Kingdom will provide the High Resolution Dynamics Limb Sounder (HIRDLS)instrument for the Chemistry-1 spacecraft.

## 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 is responsible for developing SAGE-I11 that will fly on a Russian spacecraft in 1998 and on the International Space Station in 2001 and will take advantage of both solar and lunar Occulations 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 NSCAT instrument on ADEOS-I. The first Radar Altimetry mission, Jason-1, will be as a follow-on to the TOPEX/Poseidon as a joint mission with the French Space Agency (CNES),with data provided to NOAA for operational purposes. The Laser Altimetry mission is presently planned as a dedicated domestic mission. There remain a number of instruments in the program that are also identified as flights of opportunity (i.e., ACRIM. SOLSTICE, and CERES).

## Landsat

With the launch of Landsat-7 in 1998, substantially cloud-free, sun-lit land surface imagery for detecting and characterizing regional and global change will continue. The primary contractors are Lockheed Martin Missiles and Space (LMMS)for the

Landsat-7 spacecraft, Hughes Santa Barbara Research Sensing (SBRS) for the Enhanced Thematic Mapper Plus (ETM+), and McDonnell Douglas for the Landsat-7 Delta 2 launch service. The Landsat-7 estimate includes funding for ground segment development. NOAA will be responsible for operating the satellite and the USGS will archive the data.

### Technology Infusion

This New Millennium Program (NMP) budget 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. Two Headquarters enterprises offices are coordinating their program plans to do these missions. OMTPE has joined the Office of Space Science in the New Millennium Program in order to capitalize on common work from core technology development programs and specific spacecraft and instrument studies. The program will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of mission for the next century, (i.e., spacecraft, instruments and operations). 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. These low cost, tightly controlled developments 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 efficiency of space flight missions.

Increased technology work 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. Studies are being conducted in the areas of differential absorption Light Direction and Ranging (LIDAR) and OH (hydroxyl) radiometer.

The instrument incubator initiative is expected to reduce the cost and development time of future scientific instruments for MTPE. The instrument incubator program will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The program will take detectors and other instrument components coming from NASA's fundamental technology development programs 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 MTPE missions. This includes the key follow-on instruments for the EOS.

## MEASURES OF PERFORMANCE

**Preliminary Design Reviews** - Confirms that the proposed project baseline is comprehensive (meets all program-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,

EO-1 Spacecraft review held November 1996; instrument review to be held in February 1997
Plan: February 1997

PM-1
Plan: April 1997

Chemistry-1 — Rescheduled to accommodate revised instrument schedule
Plan: March 1998
Revised: March 1999

**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.

SeaWinds — Minor schedule change
Plan: December 1995
Actual: January 1996

Landsat-7 — **Minor** schedule change
Plan: September 1995
Actual: October 1995

Aerosol SAGE III (Russian)
Plan: August 1996
Revised: TBD

EO-1 — Schedule changed to accommodate a grating spectrometer, which was recently added to the mission
Plan: April 1997
Revised: July 1997

PM-1 — Revised schedule due to late start
Plan: April 1998
Revised: August 1998

Chemistry-1 — Revised instrument schedule
Plan: June 1999
Revised: April 2000

**Instruments Delivered -** Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms with their requirements and is ready for recumng 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<br>Plan: December 1996<br>Revised: February 1997 | Delays due to miscellaneous technical problems and inefficiencies at Santa Barbara Remote Sensing |
| AM-1 last instrument<br>Plan: February 1997 | |
| Aerosol SAGE-I11 (Russian)<br>Plan: December 1997 | |
| SeaWinds<br>Plan: March 1998 | |
| EO-1<br>Plan: October 1998<br>Revised: December 1998 | Schedule changed to accommodate a grating spectrometer, which was recently added to the mission |
| PM-1 last instrument<br>Plan: December 1998<br>Revised: June 1999 | Instrument deliveries delayed |
| Chemistry-1 last instrument<br>Plan: June 2001 | |

**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.

| | |
|---|---|
| AM-1<br>Plan: February 1998 | |
| Aerosol SAGE-I11 (Russian)<br>Plan: December 1997<br>Revised: March 1998 | Added time needed to complete algorithm development |

Jason-1
Plan: December 1998

EO-1
Plan: April 1999

PM-1
Plan: July 2000

Chemistry-1
Plan: December 2001

Laser Altimetry-1
Plan: July 2002

**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.

***AM-*** 1
Plan: June 1998

Landsat-7
Plan: December 1998

ACRIM
Plan: late 1998

Aerosol SAGE-111 (Russian)
Plan: December 1998

EO-1
Plan: 1998
Revised: May 1999

Schedule changed to accommodate a grating spectrometer, which was recently added to the mission

SeaWinds
Plan: August 1999

Jason 1
Plan: December 1999

PM-1
Plan: December 2000

Chemistry-1
Plan: December 2002

Laser Altimetry-1
Plan: July 2002

SOLSTICE
Plan: December 2002

## ACCOMPLISHMENTS AND PLANS

### AM Series

Fabrication and assembly of all AM-1 spacecraft subsystems are nearing completion. The project spacecraft effort has been begun the transition from fabrication to integration and test. The propulsion subsystem will be complete in the second quarter of FY 1997. Test of the fully integrated ASTER engineering model was completed in the first quarter of FY 1996. Fabrication and assembly of all AM-1 instruments (ASTER, CERES, MISR, MODIS, and MOPITT), and integration and test of the instruments is scheduled to begin in the first half of FY 1997.

Integration and test of the AM-1 spacecraft will be completed in FY 1997. Version 1 of the science software will be delivered in the second quarter of FY 1997. The second external independent readiness review will be held prior to the start of environmental testing of AM-1 (with all instruments integrated onto the spacecraft). Environmental testing will begin in mid-FY 1997 and continue into FY 1998.

The spacecraft will be delivered to Astrotech commercial launch processing facility at the Vandenberg AFB in California where system end-to-end testing will be performed and preparation for launch will be completed. Launch is scheduled for June 1998.

### PM Series

The Request for Proposals (RFP) for the common spacecraft to provide medium-size platforms for the PM-1 and Chemistry-1 flights was released in September 1994. The planned procurement included two firm-buy and two operational spacecraft. In September 1995, TRW was selected for the common spacecraft contract. After protests were filed with the General Accounting Office, a stop work order was issued to TRW. The spacecraft protest was resolved in NASA's favor. The spacecraft contract has completed

Phase B development including a Spacecraft Configuration Audit (SCA) and Bus Requirements Review (BRR). CERES flight models 3 and 4, and MODIS flight model 1 are proceeding satisfactorily. The Brazilian Space Agency has signed a joint Memorandum of Understanding (MOU) to provide a Brazilian instrument, the HSB, for the PM-1 platform. This instrument has a significant heritage to the Advanced Microwave Sounding Unit-B (AMSU-B), which is being developed for the U.S. meteorological satellites. Japan (NASDA) has agreed to seek funding to provide an AMSR instrument. This instrument is a replacement for the Multi-frequency Imaging Microwave Radiometer (MIMR) instrument which ESA was to provide, but withdrew. Phase B development of AMSR is on schedule and proceeding satisfactorily. Final commitment by NASDA is subject to the Japanese budget process, with determination expected in April 1997.

The PM-1 spacecraft PDR will be held in the second quarter of 1997. Fabrication and assembly of the AIRS engineering model will continue through FY 1997. Assembly of the AIRS protoflight model will begin in late 1997. AMSU, CERES and MODIS will be in various stages of fabrication, test and integration. AMSR PDR and CDR will be completed in 1997. HSB PDR will also be completed in 1997.

The PM-1 spacecraft CDR will be held in the third quarter of 1998. The AIRS, AMSU, CERES and MODIS will complete fabrication, test and assembly and will be delivered in the fourth quarter of 1998. HSB will complete CDR and will be in advanced stages of fabrication, test and assembly along with the AMSR instrument. The EOS common spacecraft design will be completed. The system CDR will be completed. Fabrication of the PM-1 flight subsystems will begin in FY 1998.

**Chemistry Series**

The TES System Concept Review (SCR) was completed in FY 1996. The HIRDLS SCR has also been completed. MLS is proceeding satisfactorily during its Phase-B development process. TES, MLS and HIRDLS have shown progress and maturity in their overall design concepts including the infusion of advanced technologies such as Monolithic Microwave Integrated Circuit (MMIC) and laser based local oscillators in tera herz (THz) frequency range. The HIRDLS Phase C/D RFP was released in the fourth quarter of 1996. The Chemistry-1 mission is scheduled to fly on the second common spacecraft. During the second quarter of 1996, a special assessment study was conducted on the Chemistry-1 mission. It was aimed at reducing cost through aggressive pursuit of new technology and launch configurations. Attempts have been made to streamline each instrument's mass, power and volume without jeopardizing the science requirements. The successful completion of this study allowed the award of three-month cooperative agreement contracts to eight U.S. commercial aerospace companies. The purpose of these agreements is to explore the feasibility of low cost, mid-range spacecraft based upon existing or imminent production line commercial busses.

The HIRDLS Phase C/D contract is planned for award in the first quarter of 1997. The HIRDLS PDR will be held in June 1997. MLS and ODUS SCR's are also scheduled in 1997. MLS and TES are also planned to be in Phase C/D by late 1997. In FY 1997, the cooperative agreement results will be evaluated and a Chemistry mission decision implementation mode will be made.

During FY 1998, the HIRDLS instrument team will procure hardware for the Engineering Model (EM), and complete EM fabrication, integration, test, and calibration. This work will complete the HIRDLS detailed design phase, with culmination to the CDR in December 1998. The TES instrument PDR design and brassboard test will be completed with PDR in 1998, followed by

fabrication, integration. and test of the EM in preparation for CDR, in 1999. The MLS instrument will complete PDR brassboard test by the end of FY 1998. Long-lead procurement of certain parts will be initiated in FY 1998 for TES and **MLS.** In FY 1998, the spacecraft for the Chemistry-1 mission will begin.

## Special Spacecraft

The FY 1995 National Defense Authorization Act asked that NASA and the Navy jointly study the possible convergence of their Radar Altimetry missions (EOS Radar Altimetry program based on TOPEX/Poseidon Follow-On (TPFO) and the Navy's Geosat Follow-On (GFO) program). The final study report recommends that the EOS Radar Altimetry program, based on TPFO, be modified to meet the Navy's operational requirements. This approach would preserve NASA's science objectives, provide a timely follow-on to the TOPEX/Poseidon mission, continue established international collaboration with France, fit within the NASA budget, and satisfy Navy operational requirements with acceptable risk, at the least cost to DOD. Subsequently, the Navy withdrew from the program.

With Congressional approval to implement the Radar Altimetry mission as a modified follow-on to the successful TOPEX/Poseidon mission, NASA and CNES drafted the initial MOU between the U.S. and France. The MOU has renamed the mission as Jason-1 and divided responsibilities: CNES will provide the spacecraft and altimeter, NASA will provide the radiometer, ground system, and launch. During FY 1996, CNES initiated contracts with Aerospatiale and Alcatel for the spacecraft and altimeter, respectively, with the altimeter completing preliminary design in March 1996. The NASA radiometer design is under way at JPL and proceeding normally.

The MOU between the U.S. and France will be signed early this fiscal year. The design for the US-provided radiometer will be complete by the end of FY 1997, with both PDR and CDR scheduled to occur this year. The PDR's for the French-provided Jason-1 satellite and the US-provided ground system are scheduled for the second quarter.

During FY 1998, the US-provided radiometer will be delivered to CNES for integration with the Jason-1 satellite. The ground system will complete design.

The Laser Altimetry mission, focusing on ice topography and mass balance, continued Phase A technology development for the Geoscience Laser Altimeter System (GLAS) instrument. New mission implementation studies to reduce mission cost and shorten schedule while still achieving science objectives, were conducted. During FY 1997, the Laser Altimetry mission implementation studies will be completed, with a cooperative industry study early in the fiscal year. ***An*** approach will be selected for detailed planning, and an acquisition strategy will be developed. The GLAS instrument team will complete the technology development phase. In FY 1998, the **GLAS** instrument will enter Phase C/D, completing preliminary design before the end of the first quarter. The spacecraft Phase B/C/D procurement will be concluded with a fourth quarter FY 1998 contract award.

The SAGE-III instrument began Phase C/D development in November 1994. ***An*** implementing agreement was signed in December 1994 with the Russian Space Agency for flight of the first SAGE-III in a polar orbit on a Russian **Meteor-3M(1)** spacecraft in late 1998. A second SAGE-III instrument is planned to fly in an inclined orbit on the International Space Station in 2001.

Design and development activities have progressed on schedule with the CDR completed in August 1996. Delivery of the first SAGE III instrument is planned for December 1997. A flight opportunity for a third SAGE III Instrument with CNES is under study.

The SeaWinds CDR was completed in January 1996. The SeaWinds instrument will continue to undergo protoflight model fabrication and assembly during FY 1997. The first SeaWinds instrument activities will consist of integration and test of the instrument, with the engineering model being delivered to the Japanese in mid FY 1997. The protoflight model, the second SeaWinds instrument, is scheduled for delivery to Tsukuba, Japan in March 1998 for an August 1999 launch on the ADEOS III spacecraft by a NASDA H-II rocket from Tanegashima, Japan.

Phase B activities for the SOLSTICE instrument continue on schedule with the goal of supporting a flight opportunity in 2002. SOLSTICE Phase B activities will continue, with a critical design and cost review in early FY 1998.

The ACRIM instrument will begin Phase C/D development in early 1997. A contract was awarded to Orbital Sciences Corporation in late 1996 for a dedicated flight on a small spacecraft as a secondary Pegasus payload in the late 1998. Discussions are under way with the Canadian Space Agency (CSA) regarding a possible flight of a follow-on SOLSTICE instrument, on a CSA small spacecraft in the 2001.

## Landsat

The Landsat-7 ETM+ instrument will be delivered in early 1997. The solid state recorder will be ready for integration into the spacecraft by spring of 1997. The ground station and data handling facility will be completed in mid FY 1997.

The spacecraft will be delivered to California Space Port commercial launch processing facility at the Vandenberg AFB in California where systems end-to-end testing will be performed and preparation for launch will be completed. Launch is no later than December 1998.

## Technology Infusion

In FY 1996, a series of workshops were conducted to inform other government agencies, industry, academia and non-profit research and development organizations and to solicit inputs and partnerships for new millennium implementation. Integrated Product Development Teams (IPDT) were established to coordinate a cooperative effort to identify, develop and deliver focused advanced technologies for flight validation. This resulted in formation of the first NMP Earth Observing mission known as EO-1. An Advanced Land Imager (ALI) instrument has been selected to fly on its own dedicated spacecraft. The instrument, to be built by the Massachusetts Institute of Technology's Lincoln Laboratory, is in Phase B development. The spacecraft has successfully completed the Design Convergence Review (DCR) in the last quarter of 1996.

In FY 1997, the NMP IPDT's will establish and maintain phased technology development plans for each technology in priority order and determine the costs. NASA Headquarters will select the additional future mission sets, and contractor teams will be chosen

for the design and integration of the demonstration flight. The EO-1 instrument, ALI, and spacecraft CDR's will be held in 1997. Spacecraft and instrument fabrication, assembly and test will begin in late 1997. The second NMP mission (EO-2). will be selected in FY 1997.

Formal definition of EO-2 will be initiated in FY 1998. The EO-1 payload and spacecraft will go through integration and test during 1998, with launch planned for May 1999.

During FY 1997 and FY 1998, specific tests and demonstrations will take place in the sensor and detector technologies as we attempt to reduce existing differential absorption LIDAR systems by at least an order of magnitude in mass, power, and volume. Work will continue in the development of ultra-stable, solid state laser local oscillators for atmospheric and astronomical spectrometers suitable for measurements of atmospheric hydroxyl.

In FY 1998, funding for instrument concept exploration, which was stated in FY 1997, will continue, These first grants will explore new instrument systems and measurement techniques. The more promising concepts will then be funded to begin development of instrument brassboards or prototypes to further characterize the benefits of each approach. A second round of concept exploration grants will also be funded in FY 1998.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### EARTH OBSERVING SYSTEM DATA AND INFORMATION SYSTEM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Earth observing system data and information system ..... | 247,200 | 254,600 | 244,700 |

### PROGRAM GOALS

The goals for the EOS Data and 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 MTPE 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 MTPE 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. The design is also modular, allowing the replacement of individual components without costly overall system changes or disruptions in service. NASA is making extensive use of prototypes 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 programs at NASA and other agencies to fund needed technology development efforts of a more generic nature, i.e., communications technology. An initial version of the system, Version 0, implemented at nine Distributed Active Archive Centers (DAAC) 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 system have been redrawn. Unique developmental activity in Version 1, Release A, in support of the first flight of two EOS instruments on TRMM in 1997, has been redirected from the EOSDIS Core System (ECS) contractor to the GSFC and LaRC DAAC contractors. The remaining developmental effort previously in Release A and performed by the ECS contractor, has been folded into Version 2.0 in support of Landsat-7 and AM-1 in 1998, still to be performed by the ECS contractor.

The EOSDIS development has been divided into four major components: the EOS Data Operations System (EDOS) which has been developed by TRW, the EOSDIS Backbone Network (EBNET) which has been developed in-house by GSFC using Computer Sciences Corporation and Allied Signal, the ECS which is under development by Hughes Information Technology Systems, and the DAAC's. The EDOS receives the raw data stream from the satellites, separates the data by instrument, and performs the initial processing and back-up archiving. The EBNET delivers the real-time data to and from the operations control centers and the science data to the DAAC's. The ECS includes the flight operations segment which provides satellite and instrument command and control: the

communications and systems management segment which provides data product generation archival, and distribution: and the science data processing segment, which provides the systems to integrate all EOSDIS user functions. The DAAC's currently have a limited operational capability using EOSDIS Version 0. The EOSDIS Independent Verification and Validation (IV&V) contract is with Intermetrics Systems Services Corporation.

The EOS Data and Operations System (EDOSI element of the EOSDIS has been replanned in an effort to reduce cost and improve efficiency. Trade-off studies between the space network and ground stations for EOS data acquisition were performed. These studies resulted in changes to the architecture of EDOS, with some minor architectural implications on other elements of EOSDIS. The previous baseline architecture was to perform Level 0 data processing at the White Sands Complex (WSC). The processed data would then be distributed from WSC to the DAAC's. The assumption for that architecture was that all EOS missions would be supported via the space network. The current architecture calls for missions beyond ***AM-*** 1 to be supported by EOS ground stations (to be built in Alaska and Norway) instead of the space network. The ***AM-*** 1 mission can use either space network or ground stations. Under this new architecture, Level 0 processing will be performed at GSFC and the processed data will be distributed to the DAACs. This architecture saves money in hardware development costs for EOS spacecraft, reduces risk to PM-1 development, saves money in data transport costs, streamlines data flow, and allows for the potential commercialization of data acquisition.

Using the ECS, the nine DAAC's will process the raw data from the satellites into useful products, handle all user product searches, requests, and orders, and distribute data and information directly to the user community primarily via the national information infrastructure. The DAAC's also permanently archive all MTPE data and information for future use. To serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. Any user may access the entire MTPE data holdings from any DAAC via the Internet/world wide web as well as gaining access to affiliated systems at other agencies nationally and internationally. Each DAAC is guided by a user working group. In response to recommendations by the NRC Board on Sustainable Development, NASA is currently evaluating alternative concepts to perform the DAAC functions.

The nine DAAC's are:

- Alaska Synthetic Aperture Radar (SARI Facility, University of Alaska Geophysical Institute, Fairbanks, Alaska
- Earth Resources Observation System (EROS) Data Center, U.S. Geological Survey, Sioux Falls, South Dakota
- Goddard Space Flight Center, Greenbelt, Maryland
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center, Hampton, Virginia
- Marshall Space Flight Center, University of Alabama at Huntsville, Alabama
- National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U. S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Application Center (SEDAC), Saginaw, Michigan

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 environmental data available to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| EOSDIS Version 1<br>Plan: January 1997<br>Revised: | Support the archival and management of data from the two EOS instruments on TRMM. The ECS contractor failed the initial test readiness review of Version 1, Release A. NASA issued a stop work order for developing software unique to supporting the two EOS instruments on TRMM. This work will now be performed by contractors at the GSFC and LaRC DAACs funded by EOSDIS. |
| EOSDIS Version 2<br>Plan: October 1997<br>Revised:<br><br>Release<br>V. 2.0 January 1998<br>V. 2.1 September 1998<br><br>Operational<br>V. 2.0 May 1998<br>V. 2.1 January 1999 | Support the launch of AM-1 and Landsat-7. Version 2 will be broken into two incremental deliveries. Version 2.0 will provide all mission essential functions to support AM-1 and Landsat-7 launches. Version 2.1 will add all the functions needed for long-term data operations to support AM-1 and Landsat-7. |
| EOSDIS Version 3<br>Plan: December 1999<br>Revised: January 2000 | Support the launch of the PM-1 mission |

## ACCOMPLISHMENTS AND PLANS

The critical design review for the ECS was completed in June 1996, the EOS AM-1 and TRMM instrument teams made their first deliveries of algorithm software and documentation to the DAACs and integration and testing of the science product software with the ECS Incremental Release 1 was completed with no major problems. EOSDIS deployed an early, test version of the EDOS. Another key activity in FY 1996 was NASA's response to NRC Board on Sustainable Development's recommendations for EOSDIS. MTPE streamlined the EOSDIS ground and networks segments, achieving significant savings. After careful review by MTPE's science and interagency advisors, NASA formulated plans to evaluate an alternate approach to providing the DAAC functions that begin to shift the responsibility for product generation and publication and user services to a federation of Earth Science Information Partners (ESIP's). EOSDIS Version 0 continued successful operations in FY 1996 with the number of user accesses, products delivered, and total volume of data delivered, all showing large increases. April 1996 was the most active month thus far

with over 80,000 user accesses and just short of three tera bytes of data delivered. A key milestone for Version 0 was the deployment of a web-based search and order tool that allowed system access to a wider range of users. The EOSDIS ECS development slipped significantly in FY 1996. The slip was identified during an ECS Version 1, release A test readiness review. After NASA managers predicted a five-month delay in delivery of EOSDIS Version 1, changes to EOSDIS implementation sequence were made to maintain essential data production and distribution systems on a schedule acceptable to the users. The portions of Release A to support the TRMM mission will be implemented by upgrading existing DAAC systems. The remaining non-TRMM unique will be incorporated into Version 2, freeing the ECS contractor to focus on the AM-1 and Landsat-7 requirements. Adverse impacts to the TRMM data products are manageable, in part, because of the launch delay due to Japanese launch vehicle scheduling. Termination of EOSDIS activities at the Marshall Space Flight Center (MSFC) DAAC has started, including the transitioning of the MSFC Version 0 data products to other DAACs and federal data centers.

In FY 1997, NASA will begin a prototyping phase for formation of the environmental information federation by selecting Working Prototype Earth Science Information Partners (WP-ESIP's) from a variety of industry, research, educational, and government institutions. These WP-ESIP's will develop research data products, provide data products and services having potential commercial value, apply technology to reduce future EOSDIS cost, and collaboratively establish a working prototype federation to begin exploring federation governance and data center inter-operations. In conjunction with the other on-going activities, MTPE will begin a complete peer-review and re-certification of all the current DAACs in FY 1997.

In FY 1998, EOSDIS will begin routine production and distribution of the first EOS standard data products from the CERES and LIS instruments on the TRMM spacecraft and will provide all mission essential functions to support the AM-1 and Landsat-7 launches, Also during FY 1998, the WP-ESIP's will begin to deliver "tailored" information products and services to a broad group of science researchers, state and local agencies, commercial customers, and general interest users, furthering public access to MTPE science products and information.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### EARTH PROBES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| NASA scatterometer | 3,200 | --- | --- |
| Total ozone mapping spectrometer | 3,000 | 1,000 | 5,700 |
| Tropical rainfall measuring mission | 25,500 | 17,700 | --- |
| Earth system science pathfinders.. | 1,000 | 19,400 | 29,400 |
| Lewis & Clark | 42,600 | 5,000 | 5,000 |
| 'Light SAR" | --- | 12,000 | --- |
| Experiments of opportunity. | 4,800 | 2,100 | 600 |
| Total | 80,100 | 57,200 | 40,700 |

### PROGRAM GOALS

The Earth probes program is the component of MTPE 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 or technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth probes are the Total Ozone Mapping Spectrometer (TOMS), NASA Scatterometer (NSCAT), Tropical Rainfall Measuring Mission (TRMM), Lewis & Clark, and Earth System Science Pathfinders (ESSP).

### STRATEGY FOR ACHIEVING GOALS

#### NSCAT

Because winds are a critical factor in determining regional weather patterns and global climate, NSCAT has been developed to measure near-surface wind speeds and directions over the global oceans every two days, under all weather and cloud conditions. The NSCAT data will be useful for both oceanography and meteorology, and will permit the first global study of the influence of winds on ocean circulation, providing data on the effects of the oceans on the atmosphere and improved marine forecasting on winds and waves. The lead center for this program is JPL, and the main contractor for the instrument development is the Harris Corporation.

The NSCAT was launched in August 1996. When NSCAT was first initiated in October 1984, it was planned for launch aboard the Navy Remote Sensing Satellite (N-ROSS). After final cancellation of N-ROSS in March 1988, NSCAT was selected in August 1989, for flight on the Japanese Advanced Earth Observing System (ADEOS). Since a majority of the instrument design had been completed during the period that NSCAT was to fly on N-ROSS, the last few years of the program centered on making design changes to the instrument so that it could be accommodated on the ADEOS spacecraft and completing the instrument. The launch of the Japanese ADEOS spacecraft was slipped from February 1996 when the Japanese experienced anomalies with the spacecraft during integration and test. The ADEOS spacecraft was launched on a NASDA H-II rocket from Tanegashima, Japan on August 17, 1996.

## TOMS

The scientific objectives of the TOMS program 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 the Russian Meteor-3, launched in 1991. As with the earlier developments, GSFC has the responsibility for flight project development. and post-launch mission operations and data analysis. Prime contractors are Orbital Sciences Corporation (OSC) for the TOMS instruments and Pegasus launch services, and TRW for the TOMS-EP spacecraft. The TOMS program consists of a set of instruments (flight models 3, 4, and 5, designated FM-3, FM-4, and FM-5) and one spacecraft. Launch of the EP spacecraft by a Pegasus XL launch vehicle occurred on July 2, 1996. The FM-4 launched on the Japanese ADEOS satellite on August 17. 1996. The FM-5 was completed in 1995 and is planned for a cooperative mission with Russia in 2000.

## TRMM

The latent heat released during precipitation is a significant factor in the large-scale computer models used to predict weather and climate change, yet two-thirds of the global rainfall occurs over the tropics where rain measurements are scarce. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. In addition, TRMM will provide precise estimates of the vertical distribution of latent heat in the atmosphere. The TRMM data will be used to understand the ocean-atmosphere coupling, especially in the development of El Nino events, which form in the tropics but effects of which are felt globally, causing floods in some areas, yet droughts in others. GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. The contractors for the instruments are Hughes Santa Barbara Research Center for the Visible and Infrared Scanner (VIRS), and Hughes Space and Communications for the TRMM Microwave Imager (TMI). The TRMM Phase A study was completed in July 1988, and Phase B completed in February 1991. Award of major contracts began in May 1992. The TRMM launch is planned for November 1997.

The Japanese space agency (NASDA) is an active partner with three Earth probes, providing the ADEOS spacecraft and H-II launch vehicle for the TOMS (FM-4) and NSCAT, and the Precipitation Radar instrument and H-II launch vehicle for TRMM.

## Earth System Science Pathfinder

The Earth System Science Pathfinder (ESSP) is a science-driven program intended to identify and develop short development time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current programs. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the MTPE 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 programmatic guidelines for the first ESSP AO were specific. The first two ESSP missions will be focused on high-priority Earth system science research, limited to a total mission life cycle cost from NASA of $60 million and $90 million respectively. They will be managed by the principal investigator as a single point of contact accountable for total mission implementation and success, developed in less than 36 months from development authority to proceed, and compatible with EOSDIS standards, including the immediate release of mission data to the scientific community.

### Lewis & Clark

The Lewis and Clark missions will demonstrate different land imaging capabilities and other measurements of scientific interest to MTPE. The Lewis mission is a medium resolution hyperspectral instrument. The Clark mission is a high resolution multispectral imager. Both spacecraft will be launched in FY 1997. The "Clark" spacecraft is being built by CTA Incorporated of Rockville, Maryland. The "Lewis" spacecraft is being built by TRW and managed out of their Redondo Beach, CA office. NASA is managing both projects from NASA Headquarters. Lewis will carry 25 new technologies and Clark will carry 36, including composite structures, advanced avionics and high-efficiency power systems. Lewis will also have three advanced sensors to meet the needs of the commercial remote sensing and Earth science communities: a 384-band hyperspectral imager: a Linear Etalon Array to scan the Earth and its horizons: and an instrument to measure the Ultra-Violet UV cosmic background. Clark will have a high-resolution imager capable of 15-meter multi-spectral and 3-meter panchromatic measurements: an instrument to measure pollution in the troposphere; and an x-ray spectrometer to capture bursts from solar flares.

### "LightSAR"

The "LightSAR" program is consistent with direction included in House Report 104-812 which stipulates that NASA's FY 1998 budget request should include additional funding to accomplish this program. The "LightSAR" program is currently one of the missions competing for possible funding under NASA's Earth Systems Science Pathfinder (ESSP) program and may also compete in the upcoming MTPE Data Purchase solicitation.

### Experiments Of Opportunity

This program offers a unique capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The MTPE program 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.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Launch of TOMS flight model 3<br>Plan: March 1996<br>Actual: July 1996 | Pegasus XL/L1011 launch. Turnover of TOMS to the GSFC mission operations and data analysis team expected thirty days after launch, with data calibration and validation completed successfully. Successfully launched on a Pegasus/L1011 from VAFB on July 2, 1996. |
| Launch Lewis & Clark<br>Plan : June 1996 (Clark) and July 1996 (Lewis)<br>Revised: Under review | NASA and industry plan to meet the commitment for a 24-month period between contract initiation and launch of each spacecraft. Planned launch dates are currently under review. |
| Launch of TOMS flight model 4 & NSCAT<br>Plan: August 1996<br>Actual: August 1996 | Launched aboard the Japanese ADEOS spacecraft and H-II launch vehicle aboard ADEOS. Turnover of TOMS and NSCAT to the respective mission operations and data analysis teams at GSFC and JPL thirty days after launch, with data calibration and validation completed successfully. The successful launch on a Japanese H-II Rocket from Tanegashima. Japan occurred on August 17, 1996. |
| Launch of TRMM<br>Plan: August 1997<br>Revised: November 1997 | Launch is planned aboard the Japanese H-II launch vehicle, with turnover of TRMM operations and data analysis to TRMM ground system and science data and information system at GSFC thirty days after launch, with data calibration and validation completed. Changes in the Japanese H-II launch vehicle manifest, unrelated to TRMM, have delayed the TRMM launch. |
| Launch of first ESSP mission<br>Plan: 1999<br>Revised: 2000 | First mission launch and other characteristics will be based on mission selection through the AO. Mission selection currently scheduled for mid FY 1997. |

## ACCOMPLISHMENTS AND PLANS

TOMS EP/flight model 3 was successfully launched on a Pegasus XL from Vandenberg AFB on July 2, 1996. The TOMS flight model-4 and NSCAT instruments on the Japanese ADEOS spacecraft was also successfully launched on a Japanese rocket from Tanegashima, Japan on August 17, 1996.

In FY 1997, the interface adapter module for the interface to the Russian Meteor will begin development for the TOMS flight model-5.

In FY 1996, all remaining instruments, including Japan's precipitation radar, were delivered and integrated on the TRMM observatory. The pre-environmental test review was conducted. After performing the initial series of baseline comprehensive performance tests, the thermal vacuum test program for on-orbit performance was initiated and completed successfully. The science team delivered the at-launch algorithms which were successfully coded and tested in the TRMM Science Data and Information System (TSDIS). During FY 1997, TRMM will complete its environmental test program and perform the final comprehensive performance tests in preparation for launch from Japan. The observatory will be shipped to Japan in summer 1997 where our Japanese partner, NASDA, will begin integration to the H-II launch vehicle. The ground validation sites will be brought on-line to verify the in-situ products in TSDIS. The TRMM observatory will launch from Japan's Tanegashima Space Center in the fall 1997, and begin normal mission operations two months later. An extensive ground validation program that takes advantage of international field campaigns, as well as the verified ground sites supported by various science team members, is planned. Since the TRMM products will provide the first rainfall/latent heat profiles from space, the validation program is essential to TRMM mission success.

The first ESSP AO was released in FY 1996 with selection to occur in mid FY 1997. We are currently evaluating the proposals submitted in response to the first AO. The second ESSP AO is currently scheduled for release in FY 1998. The ESSP program will emphasize flexible approaches for augmenting the global measurement objectives of the U.S. Global Change Research Program. The recent study by the National Academy of Sciences Board on Sustainable Development (1995) outlines strategic areas for which scientific research is needed in the context of critical Earth system science issues. While these areas do not exclusively define the scientific focus for early ESSP missions, the potential, key measurement needs for which new missions may be required in the next five years are outlined. In the ESSP two-step AO process, forty-four proposals were received in response to the step one request. Thirteen of those were encouraged to respond to the second and final step based on science evaluation. Selection of ESSP teams will be accomplished and design and development of the initial missions will begin in FY 1997.

The planned launch dates for Lewis & Clark are currently under review due to the failure of the initial launch of the Lockheed Launch Vehicle (LLV-1) and development delays on Clark. The requirement for an additional LLV-1 test launch prior to launch of the Smallsats would delay their flights.

The second flight of SIR-C as part of the Shuttle Radar Laboratory (SRL-2) mission in October, 1994, was the last MTPE full space shuttle payload. Several smaller payloads were flown on the space shuttle including the Atmospheric Laboratory for Applications and Science (ATLAS-3) mission flown in November, 1994, and the Shuttle Solar Backscatter Ultraviolet (SSBUV) instrument in early FY 1996. Funding will allow for wrap-up activities for the SSBW. ATLAS, and the Measurement of Air Pollution from Satellites (MAPS) instrument. Funding for post flight activities for SRL-1 and SRL-2 missions will continue.

In addition, the experiments of opportunity program supports flight instrument opportunities on foreign spacecraft, such as the cooperative commercial flight of MAPS on the MIR space station in FY 1997 and the provision of Global Positioning Satellite (GPS)

receivers for the *Satellite de Applicaciones Cientificas-C* (SAC-C) satellite with the Argentine Space Agency. Launch of STS 85 is scheduled for July 1997. This mission will include the following instruments: Solar Constant (SOLCON), Shuttle Laser Altimeter #2 (SLA-02); and Infrared Spectrol Imaging Radiometer (ISIR).

## BASIS OF FY 1998 FUNDING REQUIREMENT

### APPLIED RESEARCH AND DATA ANALYSIS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| MTPE Science | 276,600 | 295,400 | 271,100 |
| Data purchase | (--) | (50,000) | (--) |
| Research and analysis | (184,800) | (148,700) | (161,800) |
| EOS science | (16,700) | (22,400) | (30,300) |
| Mission science teams and guest investigators | (30,800) | (36,300) | (35,800) |
| Airborne science and applications | (27,300) | (19,000) | (18,700) |
| Uncrewed aerial vehicles (UAV) | (--) | (2,000) | (5,500) |
| Advanced geostationery studies | (--) | (1,000) | (3,000) |
| Commercial remote sensing | (17,000) | (16,000) | (16,000) |
| Operations, Data Retrieval, and Storage | 73,500 | 78,000 | 54,200 |
| Mission operations | (37,800) | (41,200) | (31,600) |
| High performance computing and communications | (26,100) | (28,300) | (18,300) |
| Information systems | (9,600) | (8,500) | (4,300) |
| Total | 350,100 | 373,400 | 325,300 |

### PROGRAM GOALS

The goal of applied research and data analysis 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 applied research and data analysis program is divided into two major components: MTPE science and MTPE operations, data retrieval, and storage. The activities that report MTPE science include research and analysis, EOS science, airborne science and applications, commercial remote sensing and Uncrewed Aerial Vehicle (UAV) science program. Operations, data retrieval and storage consists of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, the purchase and management of scientific data, high performance computing and communications, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

## BASIS OF FY 998 FUNDING QUIREMENT

### MTPE SCIENCE

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Data purchase | --- | 50,000 | --- |
| Research and analysis | 184,800 | 148,700 | 161,800 |
| EOS science | 16,700 | 22,400 | 30,300 |
| Mission science teams and guest investigators | 30,800 | 36,300 | 35,800 |
| Airborne science and applications | 27,300 | 19,000 | 18,700 |
| Uncrewed aerial vehicles (UAV) | --- | 2,000 | 5,500 |
| Advanced geostationary studies | --- | 1,000 | 3,000 |
| Commercial remote sensing | 17,000 | 16,000 | 16,000 |
| Total.. | 276,600 | 295,400 | 271,100 |

## PROGRAM GOALS

The goal for the MTPE science 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 human-kind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes which pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. *An* objective of current planning is to achieve the most essential long-term objectives of EOS, and to increase effort on science with near-term payoff, within a sustainable level of funding. The observational program will become resilient, better, and cheaper in the future by (1) taking advantage of the experience being gained in preparation of the first round of EOS flight missions to reduce observing requirements in the future and to simplify the design of instruments for more cost-effective continued operation, (2) finding alternative means to carry out some of the essential measurements at the same level of quality through cooperation with other agencies and nations, and (3) infusing new ideas and technologies into the EOS program through small satellite missions which have lower infrastructure and flight costs.

## ATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science program 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 Academy of Sciences.

The strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural forces 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 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 change. A related priority is to improve understanding and prediction of seasonal-to-interannual climate variation. Reducing uncertainties in climate predictions to a season or a year in advance will dramatically improve agriculture and energy planning. In addition, the natural hazards research priority places emphasis on the use of remote sensing observations for the characterization and mitigation of drought and flood impacts. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Nino events. Special attention in measuring and modeling the relative forces like clouds, aerosols and greenhouse gases in long-term climate change, in order to improve our understanding of and prediction of climate on time scales of decades to centuries. A continuing priority is understanding the causes and consequences of changes in atmospheric ozone. Efforts are continuing to make excellent progress on resolving questions related to stratospheric ozone depletion. Emphasis is now being placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented growth of pollutant emissions in rapidly developing regions throughout the world. Work will continue in the core research programs in MTPE. These programs provide the disciplinary strength that we draw from to solve interdisciplinary priority problems.

EOS interdisciplinary science consists of focused research centered around a specific Earth science data set and interdisciplinary research geared toward a broader probe into Earth science systemic functions. The quality of data utilized is monitored by the scientists at interdisciplinary instrument computing facilities and the research is supplemented by graduate student participation in the EOS science fellowship program.

There are currently over 1,700 scientific activities being funded under the research and analysis program. Approximately 900 are carried out by universities, 100 by national research laboratories. and 700 by the federal government. The distribution of the activities encompasses forty-five of the fifty states. A policy change has been implemented where support contractors will no longer perform in-house science and research.

The airborne science program funds operations of two ER-2's and a **DC-8** aircraft. A **C-130Q** is needed to support selected Earth science investigations. The program also funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specifically modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to spaceflight. The instrumented aircraft provide remote sensing and in *situ* measurements for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting in *situ* data for our understanding of ozone depletion and stratospheric transport mechanisms.

The Commercial Remote Sensing Program (CRSP), transferred from the Office of Space Access and Technology, will continue to fund cooperative efforts with industrial 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 development of usable, customer-defined information products. Industry will make significant co-investments, funding the CRSP at about an equal level with **NASA.**

The Uncrewed Aerial Vehicle (UAV) science program, a new initiative beginning in FY 1997, will augment the MTPE airborne program by making in *situ* and remote sensing measurements initially focused on the atmosphere; staying over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of MTPE's satellite instrumentation. During FY 1997 an AO will be initiated for the selection of three or four scientific investigations carried out using commercially available UAV flight time.

The advanced geostationary studies will investigate the application of the latest technology in developing small compact geostationary satellites that will support both research and operational objectives. For example, one candidate under consideration has the capability to provide the first adequately calibrated observations from geostationary orbit that support climate research. The satellite and instrument would be developed over a four year time period. The first spacecraft would carry an imager and a second spacecraft would carry a sounder. The imager has spectral bands which provide data on cloud albedo, vegetation, cirrus clouds, cloud ice, limited ozone, and both high-level and low-level water vapor along with total water vapor. This would provide stable measurements for MTPE research that have previously been unattainable from geostationary orbit.

## MEASURES OF PERFORMANCE

The scientific issues of concern to MTPE are among the most complex and most policy relevant of any major scientific research program. The results of MTPE science are critical to the development of sound U.S. and global environmental policy, necessary for the long-term sustainable development.

| | N 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Land Cover/Land Use Change | | | |
| Last Year: | Evaluate hyperspectral remote sensing of land ecosystems. | Tropical rain forest-climate: international field campaign. | |
| This Year: | Evaluated hyperspectral remote sensing of land ecosystems. | Participate in International Field campaign on tropical rain forest climate. | Use satellite methods determined deforestation rate in South America. |

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| **Seasonal-to-Interannual Climate Variability** | | | |
| Last Year: | Evaluate role of El Nino in tropical droughts. | Provide improved sea surface winds to prediction models. | |
| This Year: | Evaluated role of El Nino in tropical droughts. | Provide improved sea surface winds for prediction models. | Improve prediction with coupled ocean-atmosphere models. |
| **Long-Term Climate System Variability** | | | |
| Last Year: | Role of total aerosol burden in climate. | Tropospheric ozone as a climate driver. | |
| This Year: | Studied role of total aerosol burden in climate. | Evaluate tropospheric ozone as a climate driver. | Determine role of volcanic aerosols in climate. |
| **Natural Hazards** | | | |
| Last Year: | Strategic plan for remote sensing of flooding/droughts. | Initiate program on flood/drought assessment. | |
| This Year: | Completed strategic plan for remote sensing of flooding and droughts. | Initiate program on flood/drought assessment. | Utilize dense array GPS for earthquake studies in southern California. |
| **Atmospheric Ozone** | | | |
| Last Year: | Ozone transport field campaign. | Establish role of Asian emissions in ozone levels. | |
| This Year: | Deployed an ozone transport field campaign. | Establish role of Asian emissions in ozone levels. | Complete assessment of stratospheric chlorine sources. |

## ACCOMPLISHMENTS AND PLANS

In FY 1997, NASA will initiate a data purchase program designed to acquire from commercial sources data sets not otherwise available that are necessary to accomplish broad research goals of Earth system science. The budget authority will be liquidated only as acceptable data is delivered and the proposed contract(s) will be executed with FY 1997 funds only after a broad, agency competition. The purchase will be managed by the Stennis Space Center. A RFP will be issued in FY 1997 to solicit data purchase proposals. It is anticipated that selection of more than one activity will occur. Such innovative methods of procurement were suggested in the Vice President's National Performance Review. Data product generation, data archival, science analysis, and all other NASA requirements are included in other elements of the MTPE budget.

In FY 1996, continuing into FY 1997 and FY 1998, the following are significant accomplishments in the five priority areas MTPE science is focusing: land cover/land use change, seasonal-to-interannual climate variability, long-term climate system variability, natural hazards, and atmospheric ozone.

| | |
|---|---|
| Land Cover/Land Use | Major progress was made in characterizing the role of the northern forests as a control on water, heat, and momentum transfers between the surface and the lower atmosphere during the Boreal Ecosystem-Atmosphere Study (BOREAS). Data has since been introduced into experimental weather prediction models significantly improving skill in predicting regional weather. |
| Seasonal-to-Interannual Climate Variability | Progress continues on forecasting of El Nino events. A study was completed in FY 1996 at GSFC that documented the critical importance of accurate characterization of soil moisture for accurate predictions of global precipitation patterns. |
| Long-Term Climate System Variability | Global observations by the SAGE and the ERBE provided a unique understanding of the climate effects of the Mount Pinatubo volcanic eruption. The NASA-Goddard Institute for Space Studies (GISS) climate model produced a prediction of effects of Mount Pinatubo aerosols on surface temperature which showed excellent agreement with subsequent observations. Analysis of data obtained on the LIDAR In-Space Technology Experiment (LITE), using the Shuttle, demonstrated the capability of space-based LIDAR to improve significantly global measurements of both natural and anthropogenic aerosols. A national network, the Solar Irradiance Research Network, of aerosol measurements has been initiated at ten secondary schools nationwide. |

| | |
|---|---|
| Natural Hazards | Recent research has demonstrated the utility of SAR for accurately documenting changes in topographic features of the earth's surface. MTPE is implementing with other government agencies a high density global positioning system geodetic array in southern California to measure surface deformation produced by underlying geological faults. Preliminary design research for a "light SAR" is investigating optimal mission characteristics for supporting the science of SAR interferometry as a method of surface change detection. |
| Atmospheric Ozone | Analysis of global data from the UARS confirmed that ozone depleting chemicals reaching the stratosphere are primarily of industrial origin. New analysis techniques developed for the TOMS provided the first global data set on surface UV radiation. These results provided the first confirmation of global trends in increasing UV radiation related to ozone depletion. The two TOMS that were launched in FY 1996 (TOMS-EP and TOMS-ADEOS) will provide data for continued ozone and UV trends determination with improved resolution and precision. |

## BASIS OF FY 1998 UNI REQUIREMENT

### OPERATIONS. DATA RETRIEVAL AND STORAGE

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Mission operations | 37,800 | 41,200 | 31,600 |
| (Upper atmosphere research satellite) | (2,900) | (5,300) | (4,800) |
| (Total ozone mapping spectrometer) | (1,300) | (1,000) | (2,800) |
| (Ocean topography experiment) | (14,400) | (12,600) | (11,500) |
| (NASA scatterometer) | (2,400) | (4,200) | (4,200) |
| (Tropical rainfall measuring mission) | (--) | (800) | (7,900) |
| (Earth science) | (16,800) | (17,300) | (400) |
| High performance computing and communications- Earth and space sciences | 26,100 | 28,300 | 18,300 |
| Information systems | 9,600 | 8,500 | 4,300 |
| Total | 73,500 | 78,000 | 54,200 |

## PROGRAM GOALS

The Operations, Data Retrieval and Storage (ODRS) program provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and future missions such as TRMM, required to understand the total Earth system and the effects of humans on the global environment. The goals of the NASA High Performance Computing and Communications (HPCC)program 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.

## STRATEGY FOR ACHIEVING GOALS

This program supports the observations and data management portion of the activities including process research, integrated modeling and prediction, and assessments that together produce a predictive understanding of the Earth system. The program will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this program 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. SBUV/2, NSCAT, 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 and SBUV/2 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 include a diverse set of institutions including NOAA (manifested ERBE sensors on NOM-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.

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 principal users include the GSFC, the European community, Japan, Canada, and Australia and a diverse group of 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), which is a core program of the International Geosphere-Biosphere Program (IGBP). The NSCAT participants include JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS spacecraft launched in 1996). and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with the Japanese to measure tropical precipitation from a low inclination orbit. Key participants involved in the Alaska ***SAR*** Facility (ASF) include the European Space Agency (ERS-1 and -2), Japan (JERS-1 and ADEOS), 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 in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

## High Performance Computing and Communications (HPCC)- Earth and Space Sciences

The NASA HPCC program consists of four vertically integrated projects. These projects are: Computational Aeroscience (CAS), Earth and Space Sciences (ESS), Remote Exploration and Experimentation (REE), and Information Infrastructure Technology and Applications (IITA). The IITA project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure.

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 eight principal investigator teams and twenty-one grand challenge investigations. The IITA Remote Sensing Databases (RSD) project uses remote sensing databases 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 data and images as well as value-added products of the data and images.

**Information Systems**

The MTPE information system program 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 program funding supports operations of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services are 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 program monitors and participates in advanced technology programs, such as the HPCC program and National Science Foundation's gigabit testbed programs. Program elements at GSFC and the 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 program 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.

## MEASURES OF PERFORMANCE

### OPERATIONAL SPACECRAFT/INSTRUMENTS

| | |
|---|---|
| Common to all missions: | |
| Archive 95% of planned data acquisition | The primary criteria for success of an operational spacecraft is to obtain 95% of the planned data acquisition. |
| Mission Specific: | |
| UARS (launched September 1991) continuing operations | The success of UARS operations is judged on providing data to support improvement in 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. |
| TOPEX/Poseidon (launched August 1992) continuing operations | 10-cm surface height is required of the spacecraft's radar altimetry instruments in determinations of speed and direction of surface currents, oceanic heat transport, and ocean topography in support of climate change monitoring. |

| | |
|---|---|
| ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations | Data from the ERBE and SAGE II must continue to be of sufficient accuracy to (1) illuminate the temporal and spatial variations in the Earth's radiation budget which drive the Earth's climate and (2) provide global data for aerosols, ozone, water vapor and nitrogen dioxide altitude profiles. |
| SBUV/2-SSBUV (launched Dec. 1984 and Sept. 1988) continuing operations | Data from the Solar Backscatter Ultraviolet/2 (SBUV/2) instruments provide column abundances and vertical profiles of atmospheric ozone. A carefully calibrated version of the same instrument, called Shuttle SBW (SSBUV) provides correlative measurements so that the TOMS and SBUV instruments flying on other spacecraft can be more accurately calibrated, and provides information on the diurnal variability of stratospheric ozone in low latitudes. |
| Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RadarSat (launched 1995) ADEOS (launched 1996) | Data received at the ASF must support determination of the properties and dynamics of sea ice and other land and sea processes in the polar regions. |
| OTD (launched 1995) continuing operations | The Optical Transient Detector (OTD) provides early acquisition of science data to support research in determining global distribution of lightning and its effects on climate change. It allows for an early engineering flight model of the Earth Observing System Lightning Imaging Sensor (LIS) instrument and concept validation, including the high speed solid-state camera system and real-time event processor, and will be a pathfinder for commercial remote sensing applications of lightning data. |
| TOMS FM-3 and FM-4 (launched July 1996, August 1996) continuing operations | Ozone monitoring systems. 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. |
| NSCAT (launched August 1996) continuing operations | NSCAT will measure surface wind speeds and directions over at least 90% of the oceans every two days in all weather and cloud conditions. |

## SPACECRAFT TO BE LAUNCHED

| | |
|---|---|
| SeaStar/Ocean Color<br>Plan: 1996<br>Revised: 1997 | Measurements will be made of up-welling radiance at eight spectral bands in the visible and near infrared portions of the spectrum at a spatial resolution of 1-kilometer. The entire cloud-free globe will be imaged once per day. Data products will include daily global maps of oceanic pigment concentration: optical attenuation length scales: and visible, water-leaving radiance. The data delivered to NASA shall meet radiometric performance specifications set forth in the contract with Orbital Sciences Corporation. These include specifications for the instrument data bands, signal-to-noise ratio, and radiance levels. The data streams will also contain all necessary information required for processing the radiance data, including predicted ephemerides and calibrations, spacecraft attitude, time, tilt, gain, and other necessary spacecraft and sensor information. |
| TRMM<br>Plan: November 1997 | TRMM is a joint United States-Japanese observatory program that will conduct systematic observations of tropical rainfall required for major strides in weather and climate research. TRMM is a U.S. spacecraft with both U.S. and Japanese instruments and will be launched on a Japanese H-II rocket. |

## ACCOMPLISHMENTS AND PLANS

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 decision 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 program, 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. The MTPE information systems program will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and the JPL.

User requirements will be met in 1997 and 1998 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX. and ERBS missions; continuing support of the SBUV/2 sensor and processing of data from the SSBW, and continuing receipt of ERS-1 and JERS-1 data at the Alaska SAR Facility. In addition, NSCAT, TOMS on ADEOS, and TOMS Earth probe are operational.

The MTPE information systems program will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and the JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the program'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 programs.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Global observations to benefit the environment ..... | 5,100 | 5,000 | 5,000 |

## PROGRAM GOALS

The goal of the Global Observations to Benefit the Environment (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.

## STRATEGY FOR ACHIEVING GOALS

The GLOBE program 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.

In order to meet the first objective of increasing international environmental awareness, the program has been 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.

The second objective to contribute to the scientific understanding of the Earth, is achievable due to the expansive data sets that result from long term, repeated measurements made in areas where data has in some cases been extrapolated in the past. To ensure the greatest possible accuracy of the data, 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.

## MEASURES OF PERFORMANCE

Double the number of
participating schools
Plan: September 1996
Actual: September 1996

Achieve participation of at least
4,000 schools
Plan: September 1997

Achieve participation of at least
6,000 schools
Plan: September 1998

## ACCOMPLISHMENTS AND PLANS

By the end of FY 1996. 2,950 schools around the world had joined GLOBE. This is nearly double the number of schools participating at the end of FY 1995. During this year, GLOBE also published a second edition of the GLOBE Teacher's Guide with updates to the GLOBE Measurement protocols and dozens of additional learning activities for GLOBE schools.

In FY 1997, GLOBE will seek to continue to increase the number of partnerships with organizations, such as universities and school districts, to help achieve program growth goals. GLOBE will also work to expand participation in the program, including the possible addition of more student measurement areas.

During FY 1998, the program will seek to continue to train an increasing number of teachers, thus facilitating the rapid growth in the number of schools participating in the program.

## BASIS OF FY 1998 UNDING REQUIREMENT

### LAUNCH SERVICES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Launch services ..... | 107,100 | 84,700 | 121,900 |

### PROGRAM GOALS

The goal of the launch services within the MTPE program is to provide the flight programs with cost-effective, on-time Expendable Launch Vehicle (ELV) launch services.

### STRATEGY FOR ACHIEVING GOALS

Funding for mission unique launch services is included under the budget for the benefiting program. While funding for the ELV's is found within the MTPE budget, program management for the ELV's rests with the Launch Vehicles Office (LVO) within NASA. The LVO aggregates NASA, NOAA, and international cooperative ELV mission requirements, establishes appropriate acquisition strategies for purchasing firm, fixed priced launch services from the U.S. industry, and imposes the scope and level of technical oversight of the commercial ELV operators' delivery of service that reflects the criticality of the mission and the level of government resources at risk. The objective is to provide affordable, 100% successful delivery to space.

Since 1987, the LVO has been employing a national mixed fleet strategy, with 100% successful launch services to MTPE payloads. The administration, procurement, and technical oversight of launch service delivery in the small and medium performance classes is managed by the Goddard Space Flight Center (Atlas-E, Titan II, Pegasus XL, and Delta II, Ultra-Lite and Med-Lite.) The intermediate and large performance class launch services (Atlas I/IIAS and Titan IV/Centaur) are managed by the Lewis Research Center. The Kennedy Space Center is delegated responsibility for technical oversight of vehicle assembly and testing at the launch site and is responsible for launch site the spacecraft processing. The current corporate participants include Lockheed Martin for AM-1 and McDonnell Douglas for Landsat-7 and RadarSat.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Launch of TOMS-EP<br>Plan: July 1995<br>Actual: July 1996 | Successfully launched aboard the Pegasus XL/L1011. |
| EOS AM-1<br>Plan: June 1998 | To be launched on an Atlas IIAS from Vandenberg AFB. |
| Landsat-7<br>Plan: December 1998 | To be launched on a Delta II from Vandenberg AFB. |
| EO-1/SAC-C<br>plan: May1999 | Med-lite class launch services. |
| JASON-1<br>Plan: December 1999 | Med-lite class launch services: co-manifest on Delta under review. |

## CC AND PL

Funding will continue in support of the EOS AM-1 and Landsat-7 launches in 1998. FY 1998 funding will be used to provide launch services for Earth Observer 1 (EO 1) with *Satellite de Applicaciones Cientificas-C* (SAC-C), EO 2, Earth System Science Pathfinder 1 (ESSP 1), ESSP 2, ESSP 3, JASON 1, EOS PM 1, and RadaRSAT 2.

**BASIS OF FY 1998 FUNDING REQUIREME"**

**ON OF FACILITIES**

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Earth system science building | 17,000 | -- | -- |
| Total.. | 17,000 | -- | -- |

**PROGRAM GOALS**

The goal of the Earth System Science Building (ESSB)project is to construct a facility that will house civil service, contractor, and visiting scientists conducting global climate change and Earth system science research using the Earth Observation System (EOS).

**FOR ACHIEVING**

Facility design and initial construction began in FY 1994 for the ESSB at the Goddard Space Flight Center. A second increment of funding was provided in FY 1995 for continuation of construction with completion funded by the FY 1996 Construction of Facilities request.

Aeronautics and
Space Transportation
Technology

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

**OFFICE OF AERONAUTICS AND SPACE [illegible] TE[illegible]OGY**

SUMMARY OF RESOU[illegible]IENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Aeronautical research and technology | 865,900 | 844,200 | 920,100 | SAT 4.1-1 |
| Advanced space transportation technology | 234,000 | 336,700 | 396.600 | SAT 4.2-1 |
| Commercial technology programs | 170.200 | 158,600 | 152.800 | SAT **4.3-1** |
| Total | 1,270,100 | 1,339.500 | 1,469,500 | |

**PROGRAM GOALS**

The goal of the Aeronautics and Space Transportation Technology Enterprise is to conduct enabling, risk reducing research with focused technology demonstrations, through industry led cooperative partnerships, which will result in the near term application of high-payoff, and critical technologies that support the efficient accomplishment of NASA mission requirements while also leading to improvement of U.S. economic competitiveness. These technologies have the potential to dramatically reduce the cost of access to space and provide for safer, more environmentally responsible, and economically superior U.S. civil and military aircraft and space launch systems, as well as improve operation of the national airspace system. The cooperative nature of these research efforts and technology demonstrations not only allows for the research funding burden to be shared with private industry, but also increases the effective transfer of research and technology products and results to private industry and other Federal agencies in order to further support increased U.S. economic competitiveness.

**STRA[illegible] FOR ACHIEVING GOALS**

NASA carries out its aeronautics and space transportation technology mission in close partnership with U.S. industry, academia and other Federal agencies such as, the DOD and the FAA.

## Aeronautics

The design of the aeronautics portion of the program reflects the continued need to address critical aeronautical safety, environmental, airspace productivity, and aircraft performance needs and to strengthen technology development in selected high-payoff areas vital to the Nation's long-term leadership in aviation. NASA's aeronautics program is focused around six strategic thrusts:

- Develop high-payoff technologies for a new generation of environmentally compatible, economic U.S. subsonic aircraft and a safe, highly productive global air transportation system:
- Ready the technology base for an economically viable and environmentally friendly high-speed civil transport:
- Ready the technology options for new capabilities in High Performance aircraft:
- Develop and demonstrate technologies for airbreathing hypersonic flight:
- Develop advanced concepts, physical understanding, and theoretical, experimental, and computational tools to enable advanced aerospace systems: and
- Develop, maintain, and operate critical national facilities for aeronautical research and for support of industry, the FAA, DOD, and other NASA programs.

To achieve these aeronautics goals, the Aeronautics and Space Transportation Technology Enterprise will increase customer review of program planning and execution: emphasize the use of low-cost experimental aircraft to increase flight opportunities: and reduce and rationalize infrastructure via centralized facility management, the designation of Centers of Excellence, and national alliance activities. The Center of Excellence concept will serve to focus the in-house research program, provide single points-of-contact for management and external customers, and ensure maximum cost effectiveness.

## Space Transportation

The design of the space transportation technology program reflects the requirement for focused efforts 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 early in the 21" century. In addition, NASA will continue to support DOD (the lead agency) for improvements to existing expendable launch vehicles in areas where NASA's unique facilities and expertise can help government and industry. Consistent with the National Space Transportation Policy, NASA, as a member of the national team, will develop technology for the next generation space transportation system, with a target of reducing launch vehicle development and operations costs dramatically after the year 2000. The Reusable Launch Vehicle (RLV) program utilizes innovative, industry led cooperative agreements to accomplish technology development research and conduct the technology demonstrations necessary to prove the feasibility of the enabling technologies that will lead to significant reductions in launch vehicle development and operations costs. Improvements to operations costs resulting from this program may also be applicable to expendable launch vehicles. The Advanced Space Transportation program focuses on development of those technologies which have the potential to reduce launch and operations costs beyond the ambitious RLV goals as well as technology required to address other strategic objectives not related to the RLV program.

By aggressively working through cooperative agreements with private industry to reduce the cost of access to space, NASA expects to make considerable headway in achieving a vital space program that meets the needs of the nation while consuming fewer resources and yet also increases the global competitiveness of the U.S. space launch industry. Due to the recent merger of the aeronautics and space technology programs into one management group, NASA is examining possible technological synergies between ongoing aeronautics and space transportation program efforts. Similarities in research requirements between programs for high temperature materials for structures and propulsion, aerodynamics and flight control may lead to opportunities for a shared return on technology research in these areas.

**Commercial Technology**

The third major program area of the Aeronautics and Space Transportation Technology Enterprise is the commercial technology program, also recently transferred from the former Office of Space Access and Technology. Since it's 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 conducting a continuous inventory of newly developed NASA technologies, maintaining a searchable database of this inventory, assessing the commercial value of each technology, disseminating knowledge of these NASA technology opportunities to the private sector, and supporting 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.

## MEASURES OF PERFORMANCE

Where feasible, all major programs within the Aeronautics and Space Transportation Technology Enterprise use clearly defined and measurable milestones to track program performance against the program plan. Major program milestones are customer negotiated and approved product and service deliverables that are identified in formal program plans. Progress against these milestones serves as a critical metric for program performance evaluation. In addition, specific quantitative or qualitative evaluation criteria have been defined as critical program performance metrics for each milestone to enable a determination of successful milestone achievement. These measures of overall program performance measure both effectiveness and efficiency relative to program plan technical, schedule and resource requirements.

To measure the Aeronautics and Space Transportation Technology Enterprise, its programs, and the manner in which they are conducted, the Enterprise has developed -- and is continually refining -- a "family" of performance metrics that cover the following:

- Specific Program Performance: Measures of program performance, both effectiveness and efficiency, relative to program plan technical, schedule and resource requirements.

  Metric: Deliverables completed as a percentage of planned deliverables.

- Customer Satisfaction: Measures of customer satisfaction with respect to hnterprise products and services.

  Metric: Triennial survey of customers on a wide range of issues, including overall customer satisfaction. The goal for FY 1998 is a 100% customer rating of 5 or above and a 50% rating at 8 or above on a 10 point scale.

  Metric: Facility Utilization Satisfaction exit interview survey. The current goal is 100% customer rating of 5 or above and a 80% rating at 8 or above on a 10 point scale.

- Other Organizational Goals and Processes: Measures of performance relative to other key multi-programmatic or non-programmatic policies and goals. A specific goal is to increase cooperative programs with the Aerospace community.

  Metric: Ten percent of the dollar value of the total aeronautics R&D program involved in cooperative activities.

- Overall Program Outcome: Measures of the long-term impact of the Aeronautics and Space Transportation Technology program on its customers and the nation as a whole.

  Metric: Identify specific examples of products and services used by customers and the impact of those products and services.

Aeronautical
Research and
Technology

**SCIENCE, AERONAUTICS AND TECHNOLOGY**

**FISCAL *YEAR* 1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY** **AERONAUTICAL RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Research and technology base | 430,600 | 404,200 | 418,300 | SAT 4.1-2 |
| Aeronautical focused programs | 435,300 | 440.000 | 501,800 | SAT 4.1-17 |
| Total | 865,900 | 844,200 | 920,100 | |
| Distribution of Program Amount by Installation | | | | |
| Marshall Space Flight Center | 5,008 | 3,856 | 3,865 | |
| Ames Research Center | 203,388 | 186,560 | 220.349 | |
| Dryden Flight Research Center | 62,575 | 55.487 | 72,594 | |
| Langley Research Center | 312,647 | 319,753 | 344,040 | |
| Lewis Research Center | 247,677 | 245,055 | 249,171 | |
| Goddard Space Flight Center | 7.044 | 7,995 | 4,129 | |
| Jet Propulsion Laboratory | 2,292 | 1,781 | 2,160 | |
| Headquarters | 25.269 | 23.713 | 23,792 | |
| Total | 865,900 | 844,200 | 920,100 | |

## BASIS OF FY 1998 FUNDING REQUIREMENT

### AERONAUTICS RESEARCH AND TECHNOLOGY BASE

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Information Technology.. | 72,300 | 73,400 | 78,600 |
| Airframe Systems | 161,000 | 134,700 | 125,100 |
| Propulsion Systems.. | 77,300 | 77,000 | 82,600 |
| Flight Research. | 67,700 | 69,600 | 82.100 |
| Aviation Operations Systems.. | 18,900 | 17,000 | 17,300 |
| Rotorcraft | 33.400 | 32.500 | 32.600 |
| Total.. | 430,600 | 404.200 | 418,300 |

### GR GOALS

The goal for NASA's Aeronautics Research and Technology (R&T) Base program is to serve as the vital foundation of expertise and facilities that consistently meets a wide range of aeronautical technology challenges for the nation. The program is intended to provide the high-technology, diverse-discipline environment that enables the development of new, even revolutionary, aerospace concepts and methodologies for applications in industry. Work within the R&T Base must lay the foundation for new focused programs -- to address specific, high-value national needs and opportunities. This work must constitute a national resource of expertise and facilities that responds quickly to critical issues in safety, security, and the environment. The same technological resources contribute to the overall U.S. defense and non-defense product design and development capabilities.

### STRATEGY FOR ACHIEVING GOALS

The technology environment for success in aerospace is characterized by continuous advances across a wide range of disciplines, as well as occasional developments of revolutionary technology. With the downsizing of research facilities and basic research capabilities in both industry and government agencies, the NASA R&T Base plays a critical role in the continual struggle for technological preeminence in the world-wide aerospace scene. The key to the strategic approach of the R&T Base is the synergistic use of facilities and expertise in a wide array of frequently related, but independently targeted, challenges. NASA, working closely with its customers, continues to lead the world in aeronautical research breakthroughs and advanced aviation concepts by pushing on a wide range of technological barriers -- in large measure through the R&T Base program. The program continues to respond to critical national needs as in the past (in areas such as fuel-efficient propulsion concepts, composite secondary structures, winglets, supercritical wings, and advanced high-lift systems). The R&T Base program is

designed to accelerate technology development, validation, and transfer. 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: aging aircraft: aircraft accident investigations: lightning effects on avionics: flight safety and security: wind shear; crew fatigue: structural fatigue: and aircraft stall/spin. The same R&T Base project teams that conduct broadly applicable disciplinary research can provide the infrastructure to support future, large-scale, focused programs. An array of major research facilities and services are located at the four aeronautical Centers of Excellence -- Ames Research Center, Dryden Flight Research Center, Langley Research Center, and Lewis Research Center. Many facilities (such as the National Transonic Facility) and expertise are unique in the U.S. and even the world.

Today, the magnitude of the challenge to the U.S. industry leadership position in aeronautics is indicated by the market share now lost to aggressive international competition. The R&T Base is designed to enhance U.S. competitiveness in aerospace technologies in both general and very specific areas. Critical elements of NASA's contribution to the aviation industry are the flow of new ideas and concepts, the ability to react quickly to unanticipated technical challenges, and the growth in fundamental knowledge that can reveal new opportunities. Key factors in the dominant role of NASA in aeronautical research include: the extensive array of research facilities required: the large disincentives for private-sector investment in long-term, high-risk aeronautical R&T -- since an individual company can rarely capture the full benefit: the length of time for the aircraft research-and-development cycle and the total investment-recoupment period: the extensive breadth and depth of technologies required to produce a superior aircraft: the public-good character of much of the research (safety, environment, certification, national security): and the unique cadre of experienced NASA technical personnel.

In FY 1997, the R&T Base Program was reorganized into **six** systems-oriented, customer-driven programs that serve the needs of the full range of aeronautical vehicle classes. NASA extended the ongoing research within the disciplinary areas for potential system-level benefits and then programmatically reorganized into appropriate new programs. Previously stated high-level program milestones are now tracked within the new programs. Airframe and Propulsion Systems programs derive naturally from typical vehicle research: the Aviation Operations Systems program addresses important interactions between vehicles and their operational environment: the Information Technology program advances and enables the infusion of computer science into information age aeronautics. The Flight Research and Rotorcraft Systems programs provide the special treatment needed for unique aspects of research operations and powered lift vehicle technologies, respectively. The R&T Base is now organized to be more flexible and responsive to its customers as agency downsizing implements measures intended to achieve enhanced efficiency and effectiveness with available research resources. The R&T Base Program continues to sponsor and conduct research using a variety of cooperative mechanisms, not only to leverage resources for technology development, but also to ensure timely technology transfers to U.S. customers.

## MEASURES OF PERFORMANCE

### Information Technology

| | |
|---|---|
| Acquire and install a distributed network storage system (Mass Storage 3) in the NAS facility to replace the current CPU-based system with at least double the capacity.<br>Plan: June 1996<br>Actual: June 1996 | Evaluate disk and network technology for a non-front-end solution with the objective to improve access time, and at the same time, increase capacity to at least double the current 1.6 terabyte capacity.<br><br>System upgrade exceeded 3.2 terabyte capacity. Completed installation of high-capacity tape robots. Increased capacity by a factor of five, to more than 500 terabytes: access time was held constant. |
| Acquire and install High Speed Processor 4<br>Plan: March 1997<br>Revised: September 1998 | Deliver to the NAS community at least a four-fold increase in computational hours.<br><br>Rephased to be consistent with processor need date. |
| Deploy Asynchronous Transfer Mode (ATM) technology in Aeronet to increase bandwidth.<br>Plan: August 1997 | Increase ATM bandwidth by factor of 3 at a cost less than or equal to that of 1994. |
| Demonstrate knowledge system prototype in test facility.<br>Plan: June 1998 | Demonstrate reduction in design cycle time by the application of intelligent information analysis and unified instrumentation. |

### Airframe Systems

| | |
|---|---|
| Demonstrate accuracy of flutter prediction.<br>Plan: September 1996<br>Actual: September 1996 | Demonstrate through benchmark tests that calculations of transonic wing flutter are accurate to within 5% through the inclusion of viscous effects.<br><br>An intensive coupling was used to model boundary layers in flows near-sound speed flows. Flutter instabilities of a thin, swept wing and a typical business-jet wing near sound speed were predicted. They compared within 5 percent with wind-tunnel data. This capability has been requested by and transferred to U.S. aircraft companies. |

| | |
|---|---|
| Demonstrate strength and toughness of emerging aluminum alloys.<br>Plan: March 1996<br>Actual: March 1996 | Confirm that data from validation coupon testing predicts properties of new aluminum alloys produced by novel intermediate rate solidification process.<br><br>Slab-cast ingots produced in-house and properties characterized. |
| Incorporate economic and risk subroutines into systems analysis methodology.<br>Plan: January 1997 | Demonstrate that method is operational and predicts effects of economics and risk on critical design parameters. |
| Complete flight validation of multi-axis control power requirements/design criteria.<br>Plan: September 1997 | Validate multi-axis control-power predictions and transfer both design criteria and guidelines to industry. |
| Demonstrate multidisciplinary modeling, synthesis, and analysis methods to enable efficient and accurate design of control systems for aircraft with complex structural, aerodynamic, and propulsion interactions<br>Plan: March 1997 | Complete and distribute the beta version of software code to industry for application. |
| Develop turbulence model for two-dimensional high-lift flows at realistic Reynolds numbers.<br>Plan: June 1997 | Create a turbulence model that predicts wake spreading and slat effects implemented into a 2-dimensional Reynolds-Averaged Navier-Stokes (RANS) code and compare results with 737 flight-test data. |
| Validate preliminary design concepts for non-circular composite structures<br>Plan: September 1998 | Fabricate and test a non-circular, composite, pressurized structural subcomponent: compare the resulting performance with analytical predictions. |
| Complete Mach 7 Research Vehicle tests in LaRC's 8-foot High-Temperature Tunnel.<br>Plan: February 1998 | Complete system check-out in Mach-7,-flight-type environment and obtain ground based data for direct comparison with flight. |

**Propulsion Systems**

| | |
|---|---|
| Demonstrate advanced, small gas-turbine combustor operating at 3,000 degrees Fahrenheit (+600 degrees Fahrenheit improvement) with minimally cooled liner.<br>Plan: March 1997 | Establish design criteria and concept for small engine combustor. Validate combustor in component rig testing. Transfer results to U S. industry. |
| Develop advanced thermal barrier coatings for ceramic composites and transfer to industry.<br>Plan: February 1997 | Demonstrate effective coating in a lab-scale test environment (coated ceramic room temperature strength retained after 100 hours at 1,052 degrees centigrade hot corrosion). |
| Deliver a preliminary conceptual analysis and design version of the Numerical Propulsion System Simulator (NPSS).<br>Plan: March 1996<br>Revised: June 1997 | Deliver the NPSS to the propulsion and aircraft industry and ensure all critical capabilities are fully functional as judged by the NASA/Industry cooperative technical focus group.<br><br>Milestone was delayed at recommendation of technical focus group to include additional design capability. |
| Provide materials systems and processing to enable compressor discharge temperatures of 1,500 degrees Fahrenheit (currently 1,200 degrees Fahrenheit).<br>Plan: April 1997 | Demonstrate a compressor disc in a spin-pit test at 1,500 degrees Fahrenheit, Transfer compressor material technology to U.S. engine companies. |
| Complete engine fabrication for advanced general aviation turbine and internal combustion engines.<br>Plan: September 1998 | Complete fabrication in time to meet FY 1999 flight test schedules. |

## Flight Research

| | |
|---|---|
| Demonstrate use of computer-controlled engine thrust.<br>Plan: September 1996<br>Actual: January 1996 | Using an MD-11 aircraft, demonstrate the ability to land safely in a simulated emergency, using computer-controlled engine thrust only.<br><br>Goal achieved ahead of schedule and under cost. Propulsion Controlled Aircraft (PCA) system proved with four landings of an MD-11 transport without using normal flight controls. PCA was flown by 25 NASA/FAA/DoD/airline/industry pilots. |
| Complete flight assessment of aerodynamic control concepts.<br>Plan: September 1996<br>Actual: July 1996 | The F-18 High Angle-of Attack Research Vehicle was used to identify and qualify strength and weaknesses of advanced control schemes, which can enhance thrust vectoring fighter aircraft performance and enable tailless configurations.<br><br>The forebody flow field of controllable strakes was explored in ground-based and flight tests. Strakes were found to be an effective yaw-power producer at high angles of attack. |
| Complete initial flight evaluation of neural-network flight controls.<br>Plan: September 1996<br>Actual: November 1996 | Demonstrate capability to identify key aircraft parameters in flight using a neural-net flight controller. |
| Demonstrate operability and real-time performance optimization of thrust vectoring exhaust nozzles.<br>Plan: September 1996<br>Actual: December 1996 | Using the F-15 research aircraft, quantify performance of "care-free" engine/nozzle operation throughout the flight envelope and demonstrate performance improvements. |
| Mach 6.5 scramjet ground test (Russian Central Institute of Aviation Motors (CIAM) contract).<br>Plan: February 1996<br>Revised: February 1997 | Demonstrate system performance and operability in a simulated environment.<br><br>Tests delayed due to funding difficulties within Russia. |
| Mach 6.5 scramjet flight test (Russian CIAM contract).<br>Plan: November 1996<br>Revised: April 1997 | Demonstrate system performance and operability in flight.<br><br>A flight test in January 1997 with an unpowered engine, boosted to test conditions by the regular rocket booster, will reduce risk: funding delays within Russia caused a schedule slip. |

| | |
|---|---|
| Complete X-36 flight evaluation.<br>Plan: June 1997 | Complete flight objectives and analysis of vehicle performance. |
| Demonstrate solar-powered remotely piloted aircraft (Pathfinder) to 70,000 feet.<br>Plan: September 1997 | Using upgraded solar cells, sunlight and FY 1997 configuration/technology on Pathfinder II airplane, achieve maximum possible altitude and duration. |
| Flight-demonstrate an inlet-distortion-tolerant control system.<br>Plan: September 1998 | Evaluate in flight, on the Advanced Control Technology Integrated Vehicle (ACTIVE) aircraft, a high-stability. integrated control system using sensed inlet distortion to enhance stability. |
| Complete unconventional-control tests for 'falling leaf' flight experiment.<br>Plan: September 1998 | Determine effectiveness of innovative control algorithm to recover from uncontrolled spin/ "falling-leaf" mode using F-18 Advanced Control Research Aircraft (ACRA). |
| Complete piston-powered flight for 8 hours at 60,000 feet.<br>Plan: September 1998 | Demonstrate record-breaking high-altitude duration with hydro-carbon fueled, multi-staged turbocharged piston engine. |
| **Aviation Operations Systems** | |
| Complete field evaluation of extended-terminal-area air-traffic-controller aids.<br>Plan: September 1996<br>Actual: September 1996 | Evaluate concepts, technologies and procedures which will support the FAA development plans.<br><br>Technology field evaluation finished by target completion date. Provided FAA with implementation recommendations including airspace safety and efficiency improvements. Evaluations at Denver and Dallas resulted in a 25 percent increase in landing rates during low visibility. |
| Demonstrate human alertness monitoring concept.<br>Plan: March 1997 | Demonstrate an operational concept for human alertness monitoring. |

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| Complete flight tests for the NASA/FAA tailplane icing program.<br>Plan: June 1997<br>Revised: September 1997 | Complete the flight-test development of tailplane aerodynamics in the presence of various ice shapes for several aircraft configuration and flight conditions.<br><br>Original completion date delayed by urgent national need related to the 1994 Eagle ATR-72 accident attributed to icing. |
| Complete icing-tunnel database of ice shapes for modem airfoils.<br>Plan: June 1998 | Develop a database of ice shapes for modem airfoils based on testing in the NASA Lewis Icing Research Tunnel. |

**Rotorcraft**

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| Assess tiltrotor noise alleviation.<br>Plan: June 1996<br>Actual: June 1996 | Complete a computational method for noise control and evaluate the method with experimental data.<br><br>Advanced computational methods for tiltrotor noise prediction were validatedand presented at two technical conferences. The codes were provided to industry with documentation. Tiltrotor noise experiment was conducted in FY 1996, but was terminated prematurely due to wind tunnel system failure. As a result, the computational codes were validated using previously acquired small-scale wind tunnel test data. |
| Implement Rotorcraft Centers of Excellence (COE) Program.<br>Plan: December 1996<br>Actual: June 1996 | Announce selections and implement cooperative agreements with up to three universities as Rotorcraft Centers of Excellence.<br><br>National Rotorcraft Technology Center (NRTC)issued a request for proposals and completed evaluation of proposals. Cooperative agreements were implemented with three universities: Pennsylvania State University, University of Maryland, and Georgia Institute of Technology. |
| Complete initial civil tiltrotor terminal area simulation using Man/Machine Integrated Design and Analysis System (MIDAS) to analyze proposed cockpit designs and crew procedures.<br>Plan: September 1996<br>Revised: June 1997 | Obtain human performance and workload data resulting from a notional civil tiltrotor cockpit design applied to a selection of feasible terminal area scenarios.<br><br>Static geometry analysis completed December 1996. Crew procedural simulation delayed due to Boeing IR&D stop-work order. Planned resumption in January 1997. |

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| Flight qualify Rotorcraft Aircrew Systems Concept Airborne Laboratory (RASCAL) research flight control system.<br>Plan: September 1997 | Complete airworthiness checks and flight qualification. |
| Demonstrate Master Cure Simulation System (MCSS) for manufacturing thick-composite rotorcraft structures.<br>Plan: December 1997 | Under National Rotorcraft Technology Center (NRTC), validate and demonstrate that master cure process molding and controller accurately predict/control thick-composite-material behavior and its rate of cure. |
| Validate advanced computational methods for the prediction of rotor/airframe interaction and unsteady aerodynamics with data acquired from advanced laser-velocimetry techniques.<br>Plan: January 1998 | Publish an assessment of the accuracy of unsteady computational aerodynamic predictions of rotor/fuselage aerodynamic interference, based on validation using advanced, non-intrusive, three-dimensional flow measurements. |

## ACCOMPLISHMENTS AND PLANS

The Airframe Systems Program made progress in FY 1996 toward the long-term goal of increased fidelity in design analysis with the establishment of a framework for an industry-standard prediction tool for boundary-layer-transition. Key high-Reynolds-number effects on control surfaces were established in the National Transonic Facility and results have been transferred to industry for use in future large-transport control system designs. Large Eddy Simulation (LES) calculations of the flow over an airfoil produced pressure distributions that agreed well with the experiment, offering the prospect of lower-cost analysis. In addition, incorporation of viscous effects into a transonic wing flutter prediction/analysis technique significantly improved its accuracy. In the pursuit of enhanced performance and service life, a novel solidification approach to materials processing was shown to produce aluminum alloys with superior combinations of strength and toughness. A technology assessment of the benefits of replacing riveted metallic structures with large, integral metallic structures was initiated. The assessment identified key materials processing technologies aimed at 30- to 50-percent reduction in metallic fuselage structures. Additionally, damage tolerance of the first fuselage composite-sandwich side panel with window belts was evaluated under load, demonstrating the feasibility of composite technology for large fuselage structure and potentially providing significant weight/cost savings. In safety, critical wake-vortex hazard-relationship data and expertise were provided to the National Transportation Safety Board (NTSB). the FAA, and industry to support their assessment of recent accidents. Systems studies identified superior vehicle designs for flight up to Mach 10 to guide configuration definition for the Hypersonic Experimental (Hyper-X) Aircraft Program to fly a series of scramjet-powered, subscale hypersonic vehicles.

During FY 1997, investigation will begin of the feasibility of large, integral, metallic structural panels for fuselage applications. The critical technology needs for resolving issues on aging aircraft will be assessed. A fatigue crack growth model will be developed, as will non-destructive inspection methods that focus on thick materials and hidden corrosion. Methods will be developed for the comprehensive assessment of the susceptibility of critical digital control computers to electromagnetic environments. Subsonic high-lift flow physics, transition prediction, and the influence of Reynolds number on skin friction will be studied, as will the benefits of blended wing/body configurations, with applications focused on very large (greater than 800 passengers) subsonic commercial transports. Survivability efforts will include development of advanced signature analysis and measurement techniques, as well as advanced concepts. The technologies required for active airframe control systems, including smart materials and integrated active control algorithms, will be studied and developed. NASA resources will be available to industry and other agencies for solving problems encountered in aircraft development and test programs. Hyper-X will begin fabrication of the first scramjet powered, subscale, "free-flyer" vehicles.

In FY 1998. the Airframe Systems program will address key technology needs to enable future subsonic, very large, long range commercial transports, including the understanding of viscous scaling for high Reynolds numbers, non-circular pressure structures, and noise-reduction issues. Integral airframe structures technology will reduce manufacturing cost through reduced part count, enabled by improved durability and damage-tolerance-analysis methodology. Advanced life-extension efforts will build upon developments from the Aging Aircraft element of the Advanced Subsonic Technology (AST) program in the areas of fatigue-crack-growth analysis and non-destructive test methods for fuselages: it will shift its focus to areas defined in the FY 1997 assessment. New design approaches for flight decks, designed to minimize human-operational errors and be error-tolerant, will be evaluated through human-error analysis. In the high-performance area, technologies will be developed that contribute to reduced gross weight and increased agility, while still maintaining compatibility with survivability requirements. These include innovative control-effector concepts, multi-element control-law design methods, active buffet alleviation and aeroelastic control. Development of new air vehicles and concepts will be actively supported through technical cooperation with DOD and industry. Aircraft systems concept-to-test efforts will address reduction of the aircraft design cycle through reduced time/cost of analytical solutions, reduced user interaction, increased fidelity, and integrated analyses. Development of smart materials, aeroacoustic analyses, and fundamental aerodynamics of laminar-flow control and high-lift systems will support these goals. The program will also pioneer long-term, high-risk fundamental technologies that offerpotential high payoff and leverage. System studies will be conducted, with industry partners, to review and assess projected performance and evaluate potential payoffs. The first Hyper-X vehicle will have completed powered pre-flight in Mach-7 flow in a large-scale wind tunnel test and will be integrated with the rocket-booster for flight.

The Propulsion Systems Program acted on recommendations from the Rayleigh Scattering Diagnostics Workshop and made significant progress during FY 1996 in measuring gas flow in confined locations such as the interior of an aircraft engine. The ultraviolet laser that was used provided stronger scattering with weaker reflections. Gas-flow parameters were measured in supersonic flow conditions. As a result of favorable systems studies, a new sub-element for General Aviation Propulsion Technologies and Manufacturing Processes was established to develop and flight demonstrate revolutionary, low-cost, environmentally-compliant propulsion systems. Cooperative agreements with the U.S. aviation industry to accomplish this were negotiated at the end of FY 1996. A requirements analysis for the Numerical Propulsion System Simulator (NPSS)was completed

in July 1996. This analysis incorporated additional needs from industrial customers. The preliminary/conceptual analysis version of NPSS will be released in June 1997.

Propulsion Systems program plans for FY 1997 include the demonstration of advanced, small gas-turbine combustors operating at 3,000 degrees Fahrenheit (+600 degree improvement) with a minimally cooled liner. The program will also validate combustor computational methods that will enable combustor designs with reduced emissions. The cooperative program with the U.S. Air Force and major engine companies on metal-matrix-composite life prediction will continue to develop 'modules" in support of materials and structures efforts aimed at 1,500-degree-Fahrenheit compressor components. A physics-based model of the forging process for engine components will be developed for industry review and evaluation. Such models are designed to provide faster and more efficient transformation of new concepts into prototypes. A demonstration of active stall control in a single-stage transonic compressor will target a 25% improvement in stall margin in the presence of distorted inflow. This technology will be extended to multistage compressors and engines in future years. An engine turbocooler will be demonstrated that uses conventional jet fuel as a heat sink up to 1,000 degrees Fahrenheit. This system requires a coating to prevent fuel coking products from depositing in the fuel lines and injectors.

During FY 1998, Propulsion Systems will focus on lower-cost alternatives to current fibers for composite materials. The program will demonstrate the alternatives in ceramic-matrix composites and document the results for use in future engine-component design. The technology barriers related to increased turbine temperature will be addressed by using advanced materials and processes to produce systems capable of temperatures above 2400 degrees Fahrenheit, as well as by developing greatly improved computational design methods for turbines with reduced cooling-flow requirements. General Aviation Propulsion will focus on component testing and fabrication of the internal-combustion and turbine engines scheduled for flight testing in FY 1999 and FY 2000.

The Flight Research program for FY 1996 accomplished flight demonstrations of several new technologies, including forebody devices for flight control in high angle-of-attack attitudes. Vectoring exhaust nozzles were also flight-demonstrated, and their performance benefits quantified. The successful use of computer-controlled engine thrust alone for emergency flight control was demonstrated. The feasibility of in-flight development of flight control laws using a neural network approach was shown. The Environmental Research Aircraft and Sensor Technology (ERAST) project has been transferred from the High Speed Research Program into the Flight Research program. In one of many activities, ERAST has provided an advanced vehicle for flight-demonstration missions with the Department of Energy. During FY 1996, the F-18 Systems Research Aircraft (SRA) accomplished several flight demonstrations, making significant state-of-the-art advancements in such technologies as: electrically powered actuators: unique, fiber-optic, fly-by-light components and position measurement devices: a laser-based Pilot Alert System (PAS) supporting the B-2 Program in detecting contrails: and an innovative, real-time structural monitoring system.

In FY 1997, the Flight Research program will complete its flight evaluation of power requirements for multi-axis control systems and will demonstrate in-flight an advanced high-stability (distortion-tolerant) integrated flight/engine control system that allows increased thrust or improved fuel economy. With these technologies, the emphasis is on demonstrating dramatic improvement in operational maneuverability performance. Operations of the ERAST remotely piloted aircraft (RPA) will be increased. The range of ERAST activities will include record-breaking flights up to altitudes of 70,000 feet by a solar-electric RPA. Another focus is the

demonstration of smart aircraft that could lead to reduced operating costs as well as reduced design-cycle time. The SRA will be used to evaluate advanced control-system components including fiber optics and electrical actuators. In high-performance aircraft, the principal emphasis is the demonstration of technologies to enhance aircraft survivability. In support of safety goals, research will be directed to the application of control-system strategies to allow confident recovery from the dangerous uncontrollable spin ("falling-leaf")mode of flight. A cooperative effort with universities and industry uses formation-flight technology as an enabler of very-long-endurance flight. The capability of NASA's flight-research testbed aircraft fleet will be enhanced through the upgrading of a supersonic cruise F-16XL to digital flight-control-system configuration. Two international cooperative programs will reach the flight-test stage. A scramjet built by the Russian Central Institute of Aviation Motors (CIAM) will investigate transitioning from subsonic (ramjet)to supersonic (scramjet)modes. In the Hypersonics Physics Experiments (PHYSX) test program, a Pegasus missile with a wing glove fixture will provide measurements of the cross-flow boundary layer at hypersonic (Mach 8)speed.

The Flight Research program in FY 1998will continue with ERAST to demonstrate, in flight, advanced technologies such as turbocharged/piston-engine flight targeted for 80,000 feet and above. Another objective is to demonstrate aircraft technologies that lead to reduced operating costs as well as reduced design-cycle time. Included will be the Active Aeroelastic Wing (AAW), which will demonstrate the concept of aircraft control through wing twist on a high-performance aircraft. The SRA will continue to be used to evaluate advanced control-system components including fiber optics, electrical actuators and air-data systems for enhanced aircraft survivability. Flight research makes use of vehicles designed specifically for technology demonstrations under the Cloaking for Survivability (CLOSUR)project. That program will emphasize the demonstration of technologies that enhance aircraft safety by application of aerodynamic and/or propulsion controls to ensure recovery from perilous combat flight situations.

During FY 1996, the Aviation Operations Systems program pursued improvments in the capacity of the nation's air-transportation system through two major field evaluations of automation aids for air traffic controllers at the Dallas-Fort Worth air-traffic control facilities. The Traffic Management Advisor (TMA) provided optimal schedule time for arriving flights, and the Final Approach Spacing Tool (FAST)recommended runway assignment and landing sequences for arriving flights. Additionally, key wind-tunnel and flight tests validated a computer model of an aircraft encounter with a wake vortex. In the pursuit of improved aviation safety, a study of Super-cooled Large Droplet (SLD) icing (the condition in the American Eagle ATR-72 crash in 1994)in the NASA Lewis Icing Research Tunnel defined the effects of SLD parameters on ice accretion. Additionally, a series of icing-tunnel tests provided data on various configurations and systems on the Department of Defense Predator (unpiloted aerial vehicle). NASA co-sponsored a symposium with the National Transportation Safety Board on "Managing Fatigue in Transportation: Promoting Safety and Productivity." The conference was structured around the NASA Fatigue Countermeasures program to transfer the lessons learned from aviation research to the other modes of transportation.

The Aviation Operations Systems program in FY 1997 will provide a database and guidelines for achieving robust air-ground communications for air traffic control with varying combinations of voice and datalink communications under differing levels of automation. The initial field test of an advanced wake-vortex sensing system will be tested at the Dallas-Fort Worth airport. In pursuit of improved aviation safety, flight tests of the NASA/FAA tailplane-icing program will be completed and will define a database of tailplane aerodynamics with and without icing for various airplane configurations and flight conditions.

Completion of the first set of flight tests for the Super-cooled Large Droplet (SLD) icing program will define the environment and support the development of simulation tools and weather forecasting/prediction tools. *An* operational concept for a new system will monitor human alertness.

In FY 1998. the Aviation Operations System program will address key barriers to improving the capacity and safety of the nation's air-transportation system. To improve safety, error-tolerant air-ground-systems integration will use human-performance principles to develop error-detecting/correcting technologies. The physiological and psychological stresses on humans will be studied, their impact defined and counter-measures explored. Methods for analyzing the stability and safety of Air Traffic Management (ATM) systems will be investigated and developed in order to enable introduction of increased automation with increased safety. Validated technologies to predict and detect wake vortex hazards will be developed to reduce operational constraints to capacity. Modeling, wind-tunnel and flight studies will be pursued to understand and forecast the icing environment, to predict its effect on aircraft flight, and to enable design of icing avoidance and protection systems in order to eliminate icing accidents and reduce operational constraints. Advanced air-traffic management concepts and technologies will be pursued in collaboration with the university community.

With the reorganization of the R&T Base, the Information Technology program now includes the Numerical Aerodynamic Simulation (NAS) Program. In FY 1996, NAS Storage (NAStore)significantly upgraded its large-scale data storage system with the use of high-density tape technology. The NAStore tape system now provides a capacity of over 500 terabytes, an order of magnitude increase in robot-accessible storage. NAStore disk capacity was also increased from 1.6 to 3.2 terabytes. NASA released a request for information to supercomputer vendors as a precursor to a request for offers on the next-generation high-speed processor. Information gathered from the responses was used to refine requirements and specifications. NASA successfully deployed its Portable Batch System (PBS) on Cray C90s, on a Cray J90, on an IBM SP2, and on the Silicon Graphics workstation cluster. This system provides batch and cluster control across all computer platforms running UNIX, including workstation clusters, shared-memory processors, and distributed-memory processors. The PBS has also been used by the High Performance Computing and Communications program to manage distributed systems. Remote access capability for aeronautical facilities users has been created by application of information-system methodologies to speed the aircraft design-and-development process.

The Information Technology program will further upgrade its NAStore data storage system by replacing controlling processors with more economic workstation systems in FY 1997. NASA will continue the research and development of a unified system-software environment for the operation of heterogeneous, distributed computer systems. Software subsystems to be studied include multi-platform accounting. Open Systems Foundation's Distributed Computing Environment (OSFDCE)and Distributed File System (DFS),and portable administration tools. The metacenter concept (acomputer protocol system to most efficiently process tasks - regardless of where the computers are located). demonstrated with the PBS on the IBM SP2, will be extended to the Cray J90 system located at ARC and GSFC. Additionally, an "aerocentric" information system will be developed by combining test techniques, instrumentation, computation, and simulation capabilities for more effective use of NASA aeronautical resources. Development of the system will be supported by emerging technology tools and an intelligent design environment to demonstrate active control systems for crucial aeronautics applications.

During FY 1998, the Information Technology program will acquire and install the High Speed Processor 4 (HSP-4) to develop Extended Operation Configuration 3 (EOC-3). Active neural control systems for crucial aeronautical applications will be developed and demonstrated, leading to significant design-cycle-time reductions and improved knowledge interfaces to aeronautical information.

The Rotorcraft program made significant progress in FY 1996 in rotor-system aeromechanics in the areas of noise reduction, vibration reduction and aerodynamic prediction capabilities for both conventional helicopters and tiltrotor configurations. The first version of the Tiltrotor Aeroacoustic Code (TRAC1) was validated, showing excellent prediction abilities for rotor blade/vortex interaction noise. Progress with advanced computational-fluid-dynamics methods allowed predictions of rotor/airframe interaction aerodynamics and assessments of the complex aerodynamic flowfields of unique new rotor/anti-torque devices. Wind-tunnel studies demonstrated greatly improved tiltrotor cruise speed using an advanced, tailored, thin tiltrotor/wing concept. Significant reductions in tiltrotor airframe vibrations were achieved using active hub-and-flap control methods. New analytical techniques for gear crack detection and failure progression were developed and validated to improve safety. NASA and Sikorsky filed a patent application for a split-torque transmission concept that reduces weight about 20 percent compared to conventional transmissions. Major progress was made by the cooperative government/industry/academia National Rotorcraft Technology Center (NRTC) program that combines the capabilities of NASA, DOD (Army and Navy), FAA, the Rotorcraft Industry Technology Association (RITA) and academia in a cooperative rotorcraft research and technology program. Technology development programs emphasized reductions in manufacturing and operating costs, low-cost composite structures, increased vehicle performance, increased reliability, and reduced noise and vibration. In addition, the Army's Rotorcraft Centers of Excellence program was integrated with NRTC.

The FY 1997 Rotorcraft program will provide two national resources for rotorcraft test activities by completing a full-span tiltrotor acoustic model (TRAM) wind-tunnel test system, and flight-qualifying a programmable-control helicopter. Work on fundamental issues in aerodynamics will be applied and validated for new configurations, and the development of modules for design tools using this knowledge and information technologies will begin. The tiltrotor wind-tunnel testing will cover active noise control and the program will work on other active and passive noise-and-vibration-reduction design techniques for both conventional helicopters and tiltrotors. Additionally, flight tests will gather data on the noise-reduction potential of optimized, low-noise, operational procedures for civil helicopters. The second full year of the NRTC will see a significant increase in multi-company industry technology projects and will encourage technology transfer between the industry participants and the government labs associated with the NRTC research program.

In FY 1998, the Rotorcraft program will focus several integrated programs. Design for Efficient and Affordable Rotorcraft (DEAR) will include new analytic tools with emphasis on composite structures. Safe All-weather Flight Operations of Rotorcraft (SAFOR) will emphasize cockpit integration/flight-control simplification, gear-train health monitoring through Health and Usage Monitoring Systems (HUMS) and predictive technologies. New, innovative rotorcraft-flight concepts will be supported through technical cooperation with the Department of Defense and industry. This work will also include evaluation of a rotor that has significantly fewer mechanical components, yet can maintain required helicopter operational control (swashplate-less rotor). The NRTC will focus on technologies to reduce costs and increase activities in flight safety and reliability. The NRTC will be used in conjunction

with alliances among the FAA, DOD, and NASA to assess the Rotorcraft program against national needs, with a view to maximizing the leverage of the NASA investment.

## SIS OF FY 1998 FUNDING REQUIREMENT

### AERONAUTICAL FOCUSED PROGRAMS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| High-performance computing and communications ..... | 32,200 | 23,300 | 45,700 |
| High-speed research.. ..... | 233,300 | 243,100 | 245,000 |
| Advanced subsonic technology ..... | 169.800 | 173.600 | 211.100 |
| Total ..... | 435.300 | 440.000 | 501.800 |

NASA's Aeronautics focused programs address selected 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 are discussed in detail on the following pages. In previous years, the focused programs included Numerical Aerodynamics Simulation (NAS) program and the Environmental Research Aircraft and Sensor Technology (ERAST) element of the High Speed Research Program. Both NAS asnd ERAST are now included within the Research and Technology Base Program -- NAS is contained within Information Technology, and ERAST is included within Flight Research.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| High-performance computing and communications - Computational Aerosciences ..... | 32,200 | 23,300 | 45,700 |

### PROGRAM GOALS

Studies have shown that high performance computing technologies have a significant positive impact on job creation, economic growth, national security, world leadership in science and engineering, health care, education, and environmental resource management. These technologies also enable the missions of many Federal agencies. The goals of the NASA High Performance Computing and Communications (HPCC)program 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.

### [ FOR ACHIEVING GOALS

The HPCC program goals are supported by five specific objectives:

1) Develop algorithm and architecture testbeds that are able to fully utilize high performance computing concepts and increase end-to-end performance:
2) Develop high performance computing architectures scaleable to sustained TeraFLOPS performance:
3) Demonstrate HPCC technologies on U.S. aeronautics, Earth science and space science research problems:
4) Develop services, tools, and interfaces essential to the National Information Infrastructure:
5) Conduct pilot programs in public use of remote sensing data that demonstrate innovative use of the National Information Infrastructure.

The NASA HPCC program was authorized by the High Performance Computing and Communications Act of 1991 and work began in FY 1992. In the first five years, progress was made towards solving "Grand Challenge" problems in science and engineering. Teams were openly and competitively selected to address "Grand Challenge" problems such as supersonic passenger aircraft simulation and global climate modeling. Major national computational testbeds were installed at Ames Research Center and Goddard Space Flight Center to study next-generation high performance computational systems and to support "Grand Challenge" research teams. In FY 1994, a new component was added to the NASA Program called Information Infrastructure Technology and Applications (IITA). It used HPCC technologies to solve National challenges in education, training, and lifelong learning: health

care: environmental monitoring: digital libraries: manufacturing and design: and access to government information. IITA activities are scheduled to end in FY 1998.

The current NASA HPCC program consists of three commonly planned projects that share an underlying work breakdown structure. These projects are: Computational Aerosciences (CAS),managed and funded by the Office of Aeronautics and Space Transportation Technology; Earth and Space Sciences (ESS), managed and funded by the Office of Mission to Planet Earth: and Remote Exploration and Experimentation (REE), managed and funded by the Office of Space Science. The primary objective of the CAS project is to significantly shorten the design cycle for advanced aerospace products such as future high-speed civil transports. The ESS project strives to enable the comprehensive modeling of large-scale, long-duration phenomenology such as global climate change or galactic evolutionary processes. **REE** has the goal of developing and demonstrating a space-qualified, spaceborne computing architecture that requires less than ten watts per billion operations per second. The Office of Education and Human Resources and the Office of Equal Opportunity Programs manage and fund the educational components of HPCC. Total direct Agency funding for the HPCC program is shown below.

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Aeronautical R&T | 32,200 | 23,300 | 45,700 |
| Mission to Planet Earth | 26,100 | 28,300 | 18.300 |
| Space Science | 600 | 3.200 | 5,600 |
| Education Programs | 2,200 | 1,400 | 4,200 |
| Minority University & Education. | 2,500 | 2.700 | -- |
| Total direct HPCC (NASA-wide) | 63,600 | 58,900 | 73,800 |

The NASA HPCC program is planned and executed in cooperation with Federal agencies, industry, and academia to exchange information about technical and programmatic needs, issues, and trends. Interagency collaboration is fostered through the National Coordination Office which has a full time staffto support the main HPCC coordinating body--the Computing, Information, and Communication R&D Subcommittee (CIC) (part of the National Science and Technology Council).

The Program Manager at Ames Research Center **is** responsible for the overall implementation of the NASA HPCC Program. NASA Headquarters provides strategic guidance on program content and direction with assistance from the NASA HPCC Executive Committee. The Committee consists of senior-level managers from the major HPCC centers and representatives from the Headquarters "stakeholder" offices: the Office of Aeronautics & Space Transportation Technology, the Office of Space Science, the Office of Mission to Planet Earth, the Office of Education and Human Resources, and the Office of Equal Opportunity Programs. The technical program is documented via a HPCC Level I Program Plan that is updated annually. Quarterly reviews are held by Headquarters to ensure that the program is achieving its stated goals and is staying within schedule and budget.

NASA has conferred with senior executives from major U.S. aerospace companies to plan the Computational Aerosciences (CAS) project to best respond to long-term customer requirements. Managers of the CAS program periodically visit and interact with industry leaders to better understand industry's critical long-term needs for computational aeroscience technologies.

The CAS program has attracted significant participation from external sources who bring expertise and resources to achieve common goals. There are two categories of involvement — Interagency Cooperative Programs and Cooperative Agreement Programs.

**Interagency Cooperative Programs:**

NSF/DARPA/NASA Digital Library Joint Research Initiative - The National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and NASA jointly sponsor the Digital Library Joint Research Initiative in order to demonstrate technologies needed to build digital libraries to electronically access NASA science data. This four-year, multi-agency effort was initiated in FY 1994 and continues through FY 1998. NASA, in conjunction with NSF and DARPA, now co-fund six research and development projects.

Scaleable Input/Output Initiative - This initiative concentrates on research to move massive amounts of data into and out of parallel computers efficiently. Working together, IBM Research, Lawrence Livermore Laboratory, Argonne National Laboratory, and NASA Ames developed a draft standard interface for parallel computer file access. By June 1997 the Message Passing Interface (MPI) is expected to be standardized by the world-recognized MPI Forum, a standards-making organization.

High Performance Networking - Compatible requirements of NASA and the Department of Energy (DOE) for high-bandwidth, wide-area experimental networking led to a joint solicitation and award to Sprint on August 25. 1994, for the incremental delivery of 45 megabits per second (Mbps), 155 Mbps, and 622 Mbps Asynchronous Transfer Mode (ATM)/Synchronous Optical Network Transmission (SONET) service to five NASA centers. The project is scheduled to be completed in September, 1997.

National HPCC Software Exchange (NHSE) - The Federal HPCC agencies working in concert with academia and DOE laboratories developed a National HPCC Software Exchange to provide an infrastructure that encourages software reuse and the sharing of software modules across organizations through an interconnected set of software repositories. This multi-agency effort was initiated in FY 1992 and continues through FY 1998.

PetaFLOPS Initiative - The current Federal High Performance Computing and Communications Program is working toward achieving teraFLOPS (one trillion floating operations per second) computing. However, far-sighted individuals in government, academia and industry have realized that teraFLOP-level computing systems will be inadequate in the future. As a result, NASA, NSF, DOE, DARPA, National Security Agency, and the Ballistic Missile Defense Organization are developing technologies to support PetaFLOP (one million-billion floating operations per second) computing systems.

**Cooperative Agreement Programs:**

NASA established a cooperative agreement in the fall of 1994 with a consortium led by IBM to develop a high performance computing capability in computational aerosciences. Additional agreements will be awarded, as required, to meet future research needs.

The Affordable High Performance Computing (AHPC) Project, initiated May 31, 1995, supported jointly by Pratt & Whitney, United Technologies Research Center, Platform Computing, CFD Research Corporation, Massachusetts Institute of Technology, State University of New York at Buffalo, MacNeal Schwendler Corporation, and NASA, is striving to prove the affordability and practicality of high performance computing using a distributed network of workstations. This cooperative agreement supports a major FY 1997 milestone to demonstrate that a distributed network of workstations is a cost-effective, reliable, high-performance computing platform for production use.

**MEASURES OF PERFORMANCE**

| | |
|---|---|
| Demonstrate multidisciplinary applications on 10-50 GigaFLOP testbed<br>Plan: September 1996<br>Actual: September 1996 | Demonstrate execution of CAS Grand Challenge applications at negotiated performance metric levels for scalability or speedup, portability, and performance. (Note: NASA Program Management Council approved change to combine CAS & ESS milestones) |
| Demonstrate end-to-end reductions in cost and time to solutions for aerospace design applications on heterogeneous systems<br>Plan: September 1996<br>Revised: September 1997 | Demonstrate at least 25% cost reduction in time to solution for 5 applications and a 5-to-1 reduction in time to solution for combustor design application<br><br>Date was tied to Cooperative Agreement Notice (CAN) completion that was delayed following lengthy approval/procurement process. |
| Demonstrate 622 Mbps interconnects over NREN.<br>Plan: September 1997 | Demonstrate 550 Mbps network performance at a minimum of three NASA centers.<br>Note: The term "high-speed" was used last year instead of the correct, more descriptive terminology "622 Mbps". |

| | |
|---|---|
| Demonstrate cost-effective, high-performance computing at performance and reliability levels equivalent to 1994 Vector Supercomputers at 25% of the capital cost<br>Plan: September 1996<br>Revised: September 1997 | Solve CAS Grand Challenge problems using a workstation cluster that performs at 250 MegaFLOPS (millions of floating operations per second) at a capital cost of less than $2.5 million.<br><br>Date was tied to CAN completion that was delayed following lengthy approval/procurement process. |
| Demonstrate integrated, multidisciplinary aerosciences applications on TeraFLOPS-scaleable testbeds.<br>Plan: September 1997 | Demonstrate execution of 50% of CAS Grand Challenge applications on teraFLOPS-scaleable testbeds. where applications meet scalability, portability and performance success criteria. |
| Install 200-250 GigaFLOPS sustained, TeraFLOPS-scaleable testbed<br>Plan: June 1998 | Install testbed and measure scaleability and performance against success criteria. |
| Demonstrate a portable, scaleable programming and runtime environment for Grand Challenge applications on a TeraFLOPS-scaleable system<br>Plan: September 1998 | Demonstrate that applications scale logarithmically with the number of processors and are portable to all current testbeds. |

## X AND PLANS

In FY 1996, the Computational Aerosciences Program achieved sustained multidisciplinary application speeds of 34 GigaFLOPS (billion floating operations per second), a speed previously unachieved by any NASA application. These results support our claim of reducing design turnaround times. Overnight simulation of a complete airplane engine will soon be achievable given the predicted capability of the FY 1998 CAS testbed. In the area of system software development, a consortium of federal and university personnel, led by Ames, developed an enhancement for Message Passing Interface (MPI) that is being reviewed for adoption by the MPI Standards Forum. This enhancement affords users a practical, portable, efficient, and flexible message passing capability for parallel processing. The installation of the 155 Mbps network service and the creation of a microeconomic job scheduler for parallel computers have enabled metacenter administration of NASA's experimental supercomputers, which are

physically dispersed across the U.S. Because of our ability to share jobs across systems, turnaround times are lower, computational capability is enhanced and utilization has increased.

Computational Aeroscience activities planned for FY 1997 include: (1) demonstrating end-to-end reductions in cost and time to solution for aerospace design applications on TeraFLOPS-scaleable testbeds: (2) demonstrating integrated, multidisciplinary applications on TeraFLOPS-scaleable testbeds: (3) demonstrating cost-effective, high-performance computing at performance and reliability levels equivalent to 1994 Vector Supercompuers at 25 percent of the capital cost [note that the initial target date for this milestone, September 1996, was set early in the planning phase, but was not corrected following the lengthy approval/procurement process]: (4) providing a production system software environment that integrates distributed workstations with TeraFLOPS-scaleable machines, and (5) demonstrating 622 Mbps National Research and Education Network interconnections.

Computational Aeroscience activities planned for FY 1998 include: (1) installing a third generation, sustained TeraFLOPS testbed to continue work in high-performance scaleable systems: (2) demonstrating a portable, scaleable programming and runtime environment for Grand Challenge applications on a TeraFLOPS-scaleable system to enhance system software development: and (3) supporting the federally coordinated Large Scale Networking Initiative -- Next Generation Internet (NGI) -- to help create the foundation for the 21st Century networks.

## BASIS OF FY 1998 FUNDING QUIREMENT

### HIGH SPEED RESEARCH

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| High-speed research..... | 233.300 | 243.100 | 245,000 |

### PROGRAM GOALS

Studies have identified a substantial market for a future supersonic airliner — or High-speed Civil Transport (HSCT) — to meet the rapidly growing demand for long-haul travel, particularly across the Pacific. Over the period from 2005 to 2015, this market could support 500 to 1,000 HSCT aircraft. creating a multi-billion dollar sales opportunity for its producers. Such an aircraft will be essential for capturing the valuable long-haul Pacific Rim market. Market studies indicate that the successful development of a domestic HSCT will result in $200 billion in sales and 140,000jobs for U.S. industry. As currently 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.

NASA is developing the technologies that industry needs to design and build an environmentally compatible and economically competitive HSCT for the 21st century. The High-speed Research (HSR) Program goal is to have the technology available to enable an industry decision on aircraft production.

### STRATEGY FOR ACHIEVING GOALS

While current technology is insufficient, studies indicate that an environmentally compatible and economically competitive HSCT could be possible through aggressive technology development. NASA is concentrating its investments in the early, high-risk stages of development and the aircraft manufacturing industry has indicated that it is willing to make a substantial investment in this program as the technological risk decreases.

NASA's HSR Program is providing a public-sector catalyst in addressing this important opportunity with U.S. industry through a two-phase approach. The first phase defined HSCT environmental compatibility requirements in the critical areas of atmospheric effects, community noise and sonic boom and established a technology foundation to meet these requirements. The second and current phase is a cooperative program with U.S. industry and is directed at developing and validating designs, design methodologies and manufacturing process technology for subsequent application by industry in future HSCT aircraft programs to ensure environmental compatibility and economic viability.

Langley Research Center (LaRC),the lead center, is responsible for policy and program implementation, project planning and funding allocation, vehicle systems engineering and integration, and direct airframe contractor interface and management. At the

NASA Aeronautics Centers (Ames Research Center (ARC),Dryden Flight Research Center (DFRC),LaRC and Lewis Research Center (LeRC)), the Center Directors provide personnel and facilities to conduct research, analysis and program management in support of the program. LeRC is also responsible for the propulsion contractor interface and management.

The team of primary HSR contractors consists of airframe, propulsion system and advanced flight deck companies. These contractors are responsible for: the research, development and validation of specific technologies: the development and assessment of a next-generation High-speed Civil Transport (HSCT)concept and configuration: the system-level integration of the advanced technologies being developed: and the conduct of associated tasks, such as mission analysis and data base development. The primary propulsion contractors are the team of Pratt & Whitney and General Electric Aircraft Engines. The primary airframe contractors are the team of Boeing and McDonnell Douglas. The advanced flight deck contractor is Honeywell International. ARC provides significant support directly to LaRC in advanced flight deck development, in computer modeling and simulation, and in economic analysis. DFRC provides support for flight-related activities including the F-16XL. LaRC is responsible for integration of all elements of the program and LeRC is responsible for propulsion systems technology integration.

The HSR Program is enhanced by participation, in coordination and cooperative efforts to exchange information and data, with other NASA organizations and federal agencies that include:

- The Atmospheric Effects of Stratospheric Aircraft Panel, which includes participation by NASA's Office of Mission to Planet Earth, Environmental Protection Agency, Federal Aviation Administration, National Oceanic and Atmospheric Administration, National Science Foundation and Department of Defense. The panel provides guidance and evaluation of research related to the effects of high-speed civil transports on the upper atmosphere;

- The FAA/NASA Coordinating Committee. which provides the framework for developing and defining HSCT certification requirements: and

- The Department of Defense, which provides a cooperative forum for advanced engine technology development via its Integrated High Performance Turbine Engine Technology (IHPTET)initiative.

## MEASURES OF PERFORMANCE

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| Select Airframre Subcomponent Materials<br>Plan: December 1995<br>Actual: December 1995 | Materials, processes and structural concepts were selected for wing and fuselage subcomponent test articles. The selection was based on material performance, structural efficiency, producibility, estimated production costs and technical risks as determined by materials testing, structural element tests, design integration trade studies and other analytical studies.<br><br>Combination of polymeric matrix composites and titanium sandwich materials were selected as primary and alternate wing and fuselage materials for further technology development. |

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| Select Preliminary Engine Nozzle and Inlet Designs<br>Plan: December 1995<br>Actual: December 1995 | The engine cycle was selected based on systems analyses which account for experimental test results. The cycle chosen provides the best combination of direct operating cost, operability, robustness, and environmental acceptability when matched to the current aircraft configuration. Nozzle selection was based on small-scale aero-acoustic testing, material feasibility and manufacturing infrastructure assessment, systems analyses, and preliminary design data for the most promising low-noise nozzle concepts. Inlet selection was based on small-scale testing, systems analyses, and historical data fior the most promising inlet concepts.<br><br>Mixed flow turbofan cycle, two-dimensional mixer-ejector nozzle and axisymmetric inlet were selected for further technology development. |
| Select HSCT Preliminary Concept<br>Plan: December 1995<br>Actual: Decemebr 1995 | Define a NASA/Industry technology baseline airplane that includes an optimized propulsion system and wing planform/high-lift combination. The selection will be based on weight, environmental requirements, robustness to changing requirements, and economic viability.<br><br>The Technology Concept Airplane defined based on technology elements satisfies weight and mission goals. |
| Supersonic Laminar Flow Control (SLFC) Flight Test Complete<br>Plan: April 1996<br>Actual: September 1996 | Complete SLFC flight experiments on F-16XL-2. Acquire critical laminar flow data over a Mach number range and altitudes for computational fluid dynamics code validation and SLFC Configuration design code development.<br><br>Minor wing glove redesign resulted in a schedule slip (not expected to impact the overall HSR program completion date). All the SLFC flight test objectives were met. Laminar flow was achieved over the speed range of Mach 1.7 to 2.0 and altitudes up to 55,000 ft. Suction requirements to maintain the laminar flow were established. SLFC is not incorporated in the baseline Technology Concept Airplane, but will be considered as an option should the technology be required in the future for the airplane to meet weight and range goals. |
| Combustor Rig (Sector) Verification Tests<br>Plan: June 1996<br>Actual: November 1995 | Verification of ultra-low NOx formation (goal: 5 grams/kilogram of fuel burned) in engine combustor sector tests.<br><br>Met emissions index goal of less than 5 grams NOx per kilogram of fuel for both the rich-burn, quick-quench, lean-burn and the lean, pre-mixed, pre-vaporized concepts. |

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| SLFC Baseline Decision<br>Plan: March 1997<br>Actual: September 1996 | The decision on whether to incorporate Supersonic Laminar Flow Control (SLFC)technology into the baseline airplane was to be based on design, production and economic system integration studies resulting from F-16XL flight experiments.<br><br>The industry HSR team evaluated the results of the SLFC completed in September 1996. This drag reduction technology has the potential of reducing vehicle gross weight by over 6 percent: however, since the potential benefits are far outweighed by the technical risk and extensive systems impact, the HSR program team does not envision using SLFC on the first generation HSCT. |
| Testbed Exhaust Nozzle Designed - Configuration & Materials<br>Plan: March 1997<br>Revised: December 1997 | Complete detailed design of selected nozzle concept and release drawings for fabrication.<br><br>Small scale tests met both aerodynamic performance and noise goals, with separate designs, but work replanned and milestone delayed in order to complete further nozzle tests required to meet both goals in one design. (Delay is not expected to impact overall HSR program completion date.) |
| Flight Controller Selection (Flight Deck Systems)<br>Plan: April 1997 | Make the final program determination of sidestick or wheel and column control inceptor as pilot control mechanism. Include examination of applicable data and studies, potential simulation evaluations, an internal industry review, and a final NASA/industry program selection. |
| Component Materials Selection<br>Plan: May 1997<br>Revised: September 1998 | Materials and structural concepts will be selected for wing and fuselage component test articles. Selections will be based on material performance, structural efficiency, and production costs as determined by testing and analytical studies.<br><br>Budget rephasing provided an opportunity to remove parallel schedules of subcomponent program and component program. The Component Materials Selection milestone now coincides with the preliminary design review. (Delay is not expected to impact overall HSR program completion date.) |

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| Combustor Configuration Selected<br>Plan: August 1997<br>Revised: May 1998 | Combustor selection will be based on results of sector testing with advanced metallic and ceramic matrix composite liners, annular rig testing, manufacturing infrastructure assessment, analyses, and preliminary designs of the two most promising combustors.<br><br>The date was revised as part of the overall combustor subelement replanning in March 1996. Delay in combustor configuration selection is due to schedule delays associated with sector testing and technical concerns associated with emission levels for one combustor concept. Overall combustor subelement technical, cost and schedule goals are expected to be met. |
| AESA Phase II (Flight Campaign Complete)<br>Plan: August 1997 | Complete on-site atmospheric observations with Northern Hemisphere Summer ER-2 flights. |
| Subcomponent Test Articles<br>Plan: July 1998 | Delivery and preparation of several wing and fuselage subcomponent articles for structural testing. |
| Preliminary Flight Deck Configuration Selected<br>Plan: July 1998 | Downselection of preliminary flight deck configuration including: choice of control inceptor: selection of basic External Visibility System concept: evaluation of terminal area guidance and control concepts: development of decision-aiding concepts: confirmation of flight deck design and automation philosophy: and provision **of** both electronic and physical cockpit mock-ups. |
| Subcomponent Test Data (Materials and Structures)<br>Plan: July 1998 | Release of data acquired during static and damage-tolerant testing of wing and fuselage subcomponent articles. |
| Phase II Assessment of Atmospheric Impact<br>Plan: September 1998 | Complete the assessment of environmental compatibility of HSCT incorporating HSR emissions reduction technology. |

## OMPLISHMENTS I PLANS

In FY 1996, the High Speed Research (HSR) program continued to develop technologies to establish the viability of an economical and environmentally-sound High Speed Civil Transport (HSCT). Wind tunnel tests of a 13.5-percent scale model with combined noise-suppression engine nozzle and high lift wing were completed. Initial analyses indicate that nozzle noise and performance characteristics (critical to an environmentally-acceptable HSCT) were undiminished by the presence of the high lift wing (also critical to a successful HSCT). Assessments of the effects that a fleet of supersonic aircraft may have on stratospheric ozone continued. Atmospheric sampling by high-altitude NASA aircraft has been completed: enhancements to atmospheric models are nearing completion: and emission scenarios for a mature HSCT fleet (i.e., 1,000 aircraft) have been completed. Finally, verification of the capability of an HSCT to meet FAA noise standards is on plan.

Major technology downselects were completed leading to the integration of the Technology Concept Airplane -- a consensus NASA/industry configuration for focusing and measuring technology development. The propulsion downselects included axi-symmetric mixed-compression inlets, mixed-flow turbofan engines, and 2-dimensional mixer ejector nozzles. The airframe down-selects included the high-lift concept, primary and secondary structural concepts using titanium and polyimide materials, and definition of the wing planform. Community noise is driving both engine and wing sizing based on potential future requirements for a fleet of HSCTs. The Supersonic Laminar Flow Control (SLFC) experiment on the F-16XL has shown that wing suction at supersonic speeds can significantly reduce drag and thus offers a potential 6-percent reduction in HSCT gross takeoff weight. However, because of the complex technology needs in structures and materials, as well as suction/power system design and integration issues, the industry decided that the SLFC technology risk could not be mitigated before the program launch of the HSCT. A combination of high- and low-resolution video sensors with a 40x50-degree field-of-view display has been selected for the synthetic vision flight deck. Two low-NOx combustor concepts are still below anticipated required emission levels based on results from sector and rig tests. The Atmospheric Effects of Stratospheric Aircraft **(AESA)** flight campaign has been augmented to reduce the uncertainties of global ozone predictions. Extensive NASA high-altitude aircraft and satellite atmospheric measurements will verify the 3-dimensional transport models being developed.

In FY 1997, the High Speed Research program will select the materials and structural concepts that will be used in the fabrication of the subcomponent test articles of the wing and fuselage. Concept selection will be based upon material performance, structural efficiency, and risks as determined by tests and analyses. Detailed design of the testbed exhaust nozzle concept will be initiated to begin fabrication of the nozzle. The Atmospheric Effects of Stratospheric Aircraft (AESA) flight campaigns will conclude. Final sampling of the stratosphere in the Northern Hemisphere by NASA high-altitude aircraft will complete the observational database as a precursor for the final assessment of High-speed Civil Transport environmental compatibility. The Tu-144 ground tests will be completed to provide propulsion inlet design data to calibrate prediction engineering codes.

In FY 1998, each of the technology areas will focus their results for integration into the Technology Configuration program milestone, scheduled for December 1998. In particular, the airframe wing and fuselage subcomponents will be fabricated and tested, and the Preliminary Design Review of the fuselage and wing large-scale components will be completed. Detailed design of the testbed exhaust nozzle concept will be completed and design drawings will be released to begin fabrication of the nozzle, which when completed will be fitted to and tested with the selected testbed engine. The selection of the core engine combustor will also be made, based upon results of completed sector testing with advanced metallic and ceramic matrix composite liners: annular rig testing: manufacturing assessment: and analyses and preliminary designs of two alternative combustors. The flight deck configuration will be selected including the control inceptor, basic external visibility system, terminal area guidance and control, decision aids, design and automation philosophy. The aerodynamics of the Technology Concept Airplane (defined in December, 1995) will be completed and nonlinear design codes will be validated for the definition of the optimized aeroelastic concept leading to the Technology Configuration Airplane (scheduled for completion in December, 1998). In addition, the Tu-144 flight tests for aerodynamics, aerothermodynamics, acoustics, and flying qualities will be completed, and the atmospheric impact of a fleet of HSCTs will be assessed using two-dimensional and three-dimensional global atmospheric models calibrated by atmospheric sampling from previous high-altitude NASA aircraft flights.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### ADVANCED SUBSONIC TECHNOLOGY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Advanced subsonic technology ..... | 169,800 | 173,600 | 211,100 |

## PROGRAM GOALS

NASA's role in civil aeronautics is to develop technology to ensure that U.S. industry is prepared to meet the demands and increasing constraints being placed on the aviation system by new safety requirements, increasingly stringent noise and emissions standards, and growing air traffic volume. These constraints slow the introduction of new technology offering improvements in aircraft performance and international competitiveness, because they increase the risk and cost of applying the technology. The goal of NASA's Advanced Subsonic Technology (AST) program is to develop high payoff technologies, in cooperation with the Federal Aviation Administration (FAA) and the U.S. aeronautics industry, to benefit the civil aviation industry and the flying public. These technologies are aimed at reducing industry costs while increasing safety, reducing civil aircraft impact on the environment and increasing the capacity of the airspace system. Success will be measured by how well NASA contributes to: (1) technology readiness that will enable U S . manufacturers to capture a larger share of the world market for civil aircraft: and (2) the effectiveness and capacity of the national air transportation system.

With competition from foreign competitors greatly increasing, technology is critically needed to help preserve the U.S. aeronautics industry market share, jobs, and balance of trade. Exports in large commercial transports make a significant contribution to the U.S. balance of trade. However, according to industry estimates, the U.S. worldwide market share has slipped from a high of 91% during the 1960's to about 67% today. Increasing congestion in the aviation system and growing concerns about the environmental compatibility of aircraft may limit the projected growth. 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. Also, more stringent noise curfews and engine emissions standards are expected before the end of this century.

During a series of meetings with aviation industry CEOs in late 1996, NASA agreed that the dramatic reduction of airplane acquisition cost is a high-priority need. To better address this need, NASA is in the process of refocusing the Integrated Wing Design, Propulsion and Composite Wing elements of the AST program to satisfy the early milestones of a more revolutionary technology to satisfy this goal.

## STRATEGY FOR ACHIEVING GOALS

The program was planned with the full involvement of both industry and the FAA. Close coordination exists between NASA and the FAA for the entire program, but particularly in those areas where there is a strong agency synergy: terminal area productivity (TAP),short-haul aircraft, noise reduction, propulsion, and environmental assessment. An ad hoc management review team, comprised of industry and governmental representatives, provided strategic oversight during the developmental stage. Industry is invited to review progress on a continuing basis to ensure that the program continues to meet those needs. The critical elements were selected on the basis of industry technology requirements to provide a focused and balanced foundation for U.S. leadership in aircraft manufacturing, aviation system efficiency and safety, and protection of the environment. In FY 1996, the TAP element was expanded to include the Advanced Air Traffic Technology program to develop technologies critical to enhancing the efficiency and productivity of aircraft/airspace operations for all users of the next generation airspace system.

A change in the program is being planned to shift the emphasis from economics to revolutionary advances in the tools necessary to design, manufacture and certify aviation systems. New integrated tools are envisioned, to enable greater reductions in the cycle time for aircraft design, manufacturing. and certification. Our objective is to place greater emphasis on revolutionary airframe design and manufacturing processes beginning with the extension of this technology to revolutionary aircraft concepts such as the Blended Wing Body (BWB). Propulsion design and manufacturing methods are expected to emphasize reduced cycle time for flow-path component design, as well as manufacturing methods technologies for fan and turbine components. Refocusing and combining all the AST Integrated Tool technologies is anticipated in order to provide significant total reductions in aircraft costs, while future efforts conducted in the next decade would bring to fruition the goal of a dramatic reduction of aircraft seat costs.

### Aging Aircraft

The industry standard practice of inspecting the civil transport airframes visually for damage is labor intensive and highly subjective. The goal of this element is to develop advanced technology that may be used by the U.S. airline operators and aircraft manufacturers to safely and economically extend the life of airplanes in the commercial jet transport fleet. The approach is to develop the prediction methodology necessary to calculate the residual strength in airframes and the advanced nondestructive evaluation technology to reliably and economically detect debonds, fatigue cracks, and corrosion. This will provide the industry with the tools to economically address the aging aircraft structural safety concerns. The program is strategically linked with complementary programs in the FAA.

### Noise Reduction

Aircraft noise is an issue, both nationally and internationally, prompting airports to operate with strict noise budgets and curfews that restrict airline operations. International treaty organizations are actively considering more stringent noise standards which will impact the growth of the aerospace industry. This program element, in cooperation with U.S. industry and the FAA, targets technologies to reduce, by the year 2000, the noise levels for future subsonic transports by 10 decibels (dB) relative to the 1992 state-of-the-art. The approach is designed to develop noise reduction technology for engine source noise, nacelle aeroacoustics, engine/airframe integration, interior noise, and flight procedures to reduce airport community noise impact, while maintaining

high efficiency. The objectives will be achieved via systematic development and validation of noise reduction technology. The timing of the technology development is consistent with the anticipated timing of recommendations for increased stringency.

**Terminal Area Productivity (TAP)**

The U.S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap exists between the industry's desired capacity and the ability of the National Airspace System to handle the increased air traffic. Additionally, current FAA standards require reduced terminal operations during instrument-weather conditions, causing delays, reducing airport productivity and increasing the cost of operating aircraft. The objective is to safely achieve clear-weather capacity in instrument-weather conditions by eliminating inefficiencies associated with runway operations conducted under instrument flight rules. In cooperation with the FAA, NASA's approach is to develop and demonstrate airborne and ground technology and procedures to reduce spacing requirements, enhance terminal air traffic management, improve low-visibility landing and surface operations, and integrate aircraft and air traffic systems while maintaining safety.

The TAP element includes development of critical air traffic technologies -- Advanced Air Transportation Technology (AATT) -- which will enable a revolutionized U.S. air traffic capability and the development of innovative concepts for countries with immature systems. The benefits are reduced costs and a larger aviation market both nationally and in countries where air traffic efficiency is limited. NASA will use its expertise in aircraft human factors and automation technologies to develop and validate high-risk technology elements of the new air traffic architecture. To assure national coordination, a blue ribbon steering committee consisting of senior government and private sector participants is guiding these activities.

**Integrated Wing Design**

Currently, the U.S. commercial transport aircraft manufacturing industry is focused on reduced costs and improved time to market through reduced product development cycle time. In cooperation with U.S. industry, NASA is developing efficient, integrated design and test procedures focused on streamlining the aerodynamic design cycle and reducing cycle times by 50 percent. This will provide an overall reduction in the total aircraft development time of one year compared to an established 1995 baseline product development cycle time. In addition, the new design and test procedures will be used to deliver validated, highly efficient wing designs for cruise and low-speed operation which include the effects of propulsion system integration. The designs will yield a four-percent reduction in Total Airplane Related Operating Costs (TAROC) relative to established 1995 baseline technology levels. Exit strategy includes final validation of cycle time and TAROC objectives by the U S. industry. Finally, it is anticipated that the validated design and test procedures will enable industry to implement technology delivered by other AST elements rapidly, leading to a 10- to 15-percent overall improvement in TAROC over the baseline.

**Propulsion**

In cooperation with the U.S. industry, NASA is developing propulsion technology with the objectives of reducing the environmental impact of future commercial engines through reduced combustor emissions and increasing the competitiveness and market share of the U.S. propulsion industry. The goals of this element are to reduce nitrogen oxide emissions, by at least 70 percent for large

engines and 50 percent for regional engines over 1996 International Civil Avionics Organization (ICAO) Standards and to improve the direct operating cost (DOC) by three percent for large engines and five percent for regional engines with fuel efficiency improvements of eight to ten percent. Research and development is focusing on low-emission combustors: affordable advanced turbomachinery; high-temperature disk and blade materials: improved controls and accessories: advanced propulsion mechanical components: and light weight, affordable engine static structures. Aerodynamic, aeroelastic, and cooling analytical models and computational tools are being developed and validated using affordable advanced turbomachinery components (which are expected to result in a 30-percent reduction in development time and manufacturing cost of cooled airfoils) and engine testing. The products of this element will be incorporated into the next generation of very-high-bypass ratio commercial engines and derivatives or enhancements of engines currently in service.

**Short Haul Aircraft**

General Aviation in the U.S. represents approximately 45 percent of the nine billion air miles flown by all civil aviation annually. However, annual U.S. production of general aviation aircraft has fallen to approximately five percent of the 1978 level. In cooperation with U.S. industry, through a 50/50 cost-share venture, NASA seeks to support revitalization of U.S. general aviation through development and deployment of advanced technologies for enhanced small aircraft transportation system capabilities. Technologies are targeted to improve the utility, safety, ease-of-use, reliability, environmental compatibility, and affordability of the next generation of general aviation aircraft for business and personal transportation. Key enabling technologies include satellite navigation, flat-panel displays, small computers, expert systems, digital data link communications, low-cost manufacturing, and ice protection. By reducing the cost of manufacturing aircraft and the time required to obtain and maintain safe, all-weather flying skills, expanded use of general aviation is expected to fuel expansion of the national economy by bringing the "off-airways" communities into the mainstream of U.S. commerce.

While the civil tiltrotor has been shown to be a viable military aircraft (e.g., 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. NASA's effort relating to the civil tiltrotor emphasizes development of technology for civil tiltrotor configurations, and 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, proprotor noise must be reduced by 6 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 6 dBA reduction. To enable these approaches to be safely flown under all weather conditions, integrated and automated control laws and displays will be developed. The capability to recover from an engine failure requires the development of contingency power options that can provide single-engine hover capability without excessive engine weight.

**Environmental Impact and Technology Integration**

Environmental Impact and Technology Integration is a combination of two elements identified in previous years -- the Technology Integration and Environmental Impact element, and the Environmental Research Aircraft & Sensor Technology element.

Environmental Impact develops a scientific basis for assessing the atmospheric impact of subsonic commercial aircraft. The goals are to determine the current and future impact of aviation on the atmosphere: and to provide assessment reports of future international ozone and climate to serve as the basis for possible cruise emissions standards to be recommended by the International Civil Aviation Organization. Overall program direction and selection of investigators will be guided by an advisory panel comprised of respected members of the scientific and aviation communities. Elements of atmospheric research (e.g. modeling, laboratory studies, and atmospheric observations) are being complemented by studies unique to the aviation problem (engine exhaust characterization, near-field interactions, and operational scenarios). Sensors will be developed to perform atmospheric observations to determine the chemical and physical characteristics of the atmosphere relative to possible effects of aircraft chemistry (i.e., primarily ozone) and climate. The sensors will be used aboard the NASA DC-8 flying laboratory during field campaigns.

Technology Integration allows for a full understanding of the relative payoff of emerging technologies. A systems analysis capability is essential in the development of a credible assessment of the impact of NASA aeronautics technologies on the U.S. industry. As this capability evolves, it supports the Office of Aeronautics and Space Transportation Technology and NASA Research Centers in planning and managing the aeronautics program. Understanding the implication of NASA's technology investment on the aviation system minimizes the time intervals from idea generation to implementation, to industry development, and most importantly, to technology transfer.

## Composites

The aircraft industry's resistance to using composites is related to economics and reparability/maintainability. While the current demonstrated level of composites technology can promise improved aircraft performance and lower operating costs through reduced structural weight, it does so with increased manufacturing costs, currently twice the cost of aluminum. The program goal is full-scale verification of affordable composite primary wing structures with an additional goal of demonstrated structure robustness through simulated service experience and repair by airline personnel. The primary objectives of the composites element are to reduce the weight of civil transports by 10 to 30 percent and their acquisition cost by 10 to 20 percent compared to today's metallic transports. This translates into a potential five percent reduction in total aircraft-related operating costs (TAROC) to the airlines and increases the competitiveness of the U.S. built transports. In cooperation with industry and the FAA, research is performed to validate the technology for the application of new composites manufacturing techniques.

## MEASURES OF PERFORMANCE

### Aging Aircraft

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| Verify methodology to predict the residual strength of airframe structures.<br>Plan: June 1996<br>Actual: June 1996 | Deliver to industry verified (under combined loads) structural integrity analysis codes (FRANC3D/STAGS) able to predict reduction in residual strength of a fuselage with widespread fuselage damage and accidental discrete source damage.<br><br>Computer codes (FASTRAN, FADD, FRANC2D and FRANC3D/ STAGS) have been verified and transferred to industry along with engineering handbooks. |
| Complete field demos for tech transfer to industry<br>Plan: April 1998 | Develop specialized engineering analysis tools to quantitatively evaluate inspection findings by computing remaining life, inspection intervals, and the residual strength of structural repairs. Complete field demonstrations of non-destructive evaluation (NDE) prototype instruments to illustrate technology utilization, and conduct focused workshops to transfer all technology to the instrument manufacturing industrial community. |

### Noise Reduction

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|---|---|
| Validate concepts for 3-decibel jet and fan noise reduction relative to 1992 technology.<br>Plan: September 1996<br>Actual: December 1996 | Experimental verification through high-fidelity, scale model, 1.5-6 bypass ratio engine simulator concepts (e.g. optimized fan/stator geometries, improved nacelle duct treatment).<br><br>First quarter FY 1996 furlough caused a three-month delay in testing models in the Lewis Research Center 9x15 tunnel due to wind tunnel scheduling. |

### Terminal Area Productivity

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| Transport Systems Research Vehicle (TSRV) ready to perform terminal area research<br>Plan: April 1998 | Provide flight research capability for support of Terminal Area Productivity technology development and demonstration. |

**Integrated Wing Design**

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|---|---|
| Establish swept wing suction panel design criteria<br>Plan: September 1996<br>Actual: September 1996 | Establish hole size, spacing and orientation for optimized suction requirements for laminar flow aircraft.<br><br>Reductions in overall suction requirements of up to 15% were obtained via wind tunnel tests using 75% fewer holes than previous technology. |
| Mid-term assessment of impact on TAROC and design-cycle time compared to the baseline configuration.<br>Plan: September 1997 | Evaluation of technology improvements will result in at least 1% improvement in TAROC and 20% improvement in aero design-cycle time. |

**Propulsion**

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|---|---|
| Complete 60-Atmosphere Combustion Test Rig<br>Plan: March 1996<br>Actual: March 1996 | Operate national facility for testing large-engine sector combustors and full annular combustors for regional engines.<br><br>Full facility systems testing completed and system operational for testing low emissions flametube concepts. Provides new, world class capability. |
| Evaluate flame tube combustor concepts<br>Plan: March 1998 | Advanced tube combustor concepts will be evaluated for their potential to reduce NOx by conducting flame tube experimental tests at 60 atmospheres to simulate engine combustor operating conditions. |

**Short Haul Aircraft**

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|---|---|
| Complete flight acoustic database for the civil tiltrotor.<br>Plan: January 1996<br>Actual: January 1996 | Comprehensive flight acoustic database acquired for XV-15 aircraft, including conventional and step approach paths. Sufficient flight acoustic data acquired for V-22 to enable scaling law validation.<br><br>Early flight test results using optimized flight procedures indicate potential for a 3.2 dBA reduction (30%) in proprotor noise. These early results show good potential for meeting the final goal of 6 dBA reduction from optimized flight procedures. |

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|---|---|
| Define general aviation transportation system operational, functional and performance requirements.<br>Plan: February 1997 | Define and publish small-aircraft transportation system requirements for users, aircraft and infrastructure. |

**Environmental Impact and Technology Assessment**

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|---|---|
| Atmospheric observations from DC-8 Flying Laboratory.<br>Plan: September 1996<br>Actual: September 1996 | Gather data from the first on-site observations dedicated to subsonic scientific assessment of the effects of contrails on Earth's radiation and the potential environmental effect of aircraft soot or sulfate.<br><br>The aircraft succeeded in sampling environmental conditions needed to fulfill all five of the primary mission objectives. Instrumentation obtained a data set of unprecedented scope on cirrus cloud particles, cloud radiative properties, and aircraft exhaust particles and contrails. Emissions of an advanced engine were characterized over a range of simulated cruise conditions. Wake/vortex dynamics models were validated with ground-based lidar observations of LaRC B-737 exhaust. |
| Release first-generation aviation system analysis capability.<br>Plan: December 1996<br>Revised: January 1997 | Deliver a computerized process that provides AST management with easy access to analysis and data bases for identifying potential benefits of AST technologies. |

**Composites**

| | |
|---|---|
| Document wing configuration requirements.<br>Plan: Decemebr 1996<br>Actual: September 1996 | Document composite wing design that meets all technical requirements, and all cost and weight targets.<br><br>Wing design documented. Current analysis indicated wing will meet goals of 5-20% reduction in wing manufacturing cost, 25-40% reduction in wing weight and 5-10% reduction in aircraft direct operating cost (relative to 190-passenger airplane with an aluminum wing). |

## ACCOMPLISHMENTS AND PLANS

### Fly-By-Light/Power-By-Wire (FBL/PBW)

In FY 1996, the detailed design of the selected PBW system was completed for a two-engine civil transport. The electromagnetic environment modeling code was validated using results from Transport Systems Research Vehicle (TSRV) flight tests. A preliminary flight test assessment of the integration of basic FBL components was completed and provided to industry. The results were incorporated in the commercial transport verification and validation plan. On October 1, 1996, the FBL/PBW element was terminated in response to FY 1997 budget reductions.

### *Aging* Aircraft

In FY 1996, the analytical tools to predict the residual strength **of** a fuselage with widespread fatigue damage and accidental discrete source damage was experimentally verified through large-scale panel testing in cooperation with industry. After verification and subsequent refinement, the codes were provided to industry. Starting in FY 1996, and continuing through FY 1997, field testing and refinement of signal-processing techniques for all of the prototype non-destructive evaluation (NDE) systems will be conducted. Technology transfer and commercial product licensing agreements for the NDE technology have been pursued, and in FY 1998, field demonstrations for technology transfer to industry will be completed.

### Noise Reduction

In FY 1996, experiments were conducted on concepts to improve nacelle duct noise treatment effectiveness. Testing was completed on concepts for jet and fan noise reduction. Other activities included the completion of an engine noise database: the release of the community noise impact model: and a demonstration of an active structural acoustic control system on a business aircraft. In FY 1997, the most promising low-noise concepts for fan/jet/core will be selected based on advanced acoustic analyses and model tests. Additional planned work includes validating passive and adaptive linear treatment models: modeling and quantifying the flap-edge noise source: selection of an active noise control concept for engine demonstration: and demonstrating active control of boundary-layer-induced interior noise. In FY 1998, validation of the most promising active noise control concepts to reduce engine fan noise will be conducted. Benefit assessments on airframe noise reduction concepts will be completed. Other activities include identifying the most practical airframe noise reduction concepts by using subscale testing.

### Terminal Area Productivity

In FY 1996, a flight demonstration of integrated airport surface automation concepts was conducted to identify inter-system issues between Global Positioning System (GPS), radar and other surface movement technologies. In FY 1997. cockpit systems flight tests will be performed for landing, roll-out, take-off and taxi to develop algorithms, displays and data bases for control systems to minimize runway occupancy time. The cockpit systems flight tests will be performed to demonstrate the Taxi-Navigation And Situation Awareness (T-NASA) System to assist the crew in maintaining (or improving) the safety and efficiency of taxi operations in visibility down to 300 feet runway visual range. T-NASA is a 3-component system comprised of an electronic moving map display, a head-up perspective taxi display, and a 3-D audio alert system. The system is being developed to provide navigation and

situation awareness information in the flight deck for taxi on the airport surface. In FY 1998, the 757 flight research capability buildup will be completed, thereby making the aircraft ready for TAP demonstrations.

In FY 1996, the AATT effort began with system concept studies addressing both airborne and ground elements of candidate system architectures created through integration of aircraft guidance and air traffic controls technology. Study results provided a sound basis for future concepts and technology selection and for defining the next generation air traffic system requirements. In FY 1997, analyses, simulations, and experiments will be conducted to quantify the probability of conflicts, define requirements, and accelerate the development of conflict-probe and other technologies to prepare for their evaluation under a future field deployment at an FAA Air Route Traffic Control Center. In FY 1998, efforts will continue to explore distributed air/ground traffic separation concepts: expand air traffic concepts to include all user classes: and initiate a study to extend the decision science tools to the Northeastern Corrdidor.

**Integrated Wing Design**

In FY 1996, a NASA/Industry team conducted analysis of the Laminar Flow Control (LFC) database to establish swept-wing suction panel design criteria for a future, low-drag laminar flow aircraft design. Model fabrication of the externally blown flap configuration was completed in preparation for FY 1997 wind tunnel testing. In FY 1997. a low-speed, pressure-sensitive paint (PSP) diagnostic and preliminary load system will be developed to significantly reduce wind-tunnel test cost. **An** integrated computer aided design/computational fluid dynamics (CAD/CFD) grid generation scheme will also be pursued to reduce computational process time. Inverse pylon/nacelle design tools will be available to incorporate new engine installations on existing wings. Reynolds number effects for externally blown flaps will be established in order to develop simpler high-lift systems at current performance levels. U.S. aircraft manufacturing industry will conduct a mid-term assessment on progress toward reduced cycle time and TAROC objectives. In FY 1998, multipoint wing design tools and cruise multicomponent wing/propulsion airframe integration design tools will be calibrated.

**Propulsion**

In FY 1996, a new and unique high-pressure and high-temperature Advanced Subsonic Combustor Rig (ASCR) was checked out and readied to provide valuable assessments of low-emission combustors for advanced engines. The combustor rig has significantly improved the U.S. capability in cumbustor testing by providing a capability to operate at pressures in excess of 50 atmospheres, temperatures of more than 3000°F. and air flows of 38 pounds per second. The first test evaluated a lean direct injector low-emission combustion concept for future aircraft engines. In FY 1996, aerodynamic, aeroelastic, and cooling technology was aimed at developing and validating industry's affordable advanced turbomachinery. Technology development efforts were initiated for advanced propulsion mechanical components, controls, and materials. In FY 1997. extensive screening tests of advanced low-emission combustor concepts for both large and regional engine applications will be conducted. In FY 1998. a low-cost polymer matrix composite manufacturing process will be demonstrated, flame tube combustor concepts will be evaluated by experiments in the ASCR, and prototype disk manufacturing will be demonstrated.

## Short Haul Aircraft

In FY 1996, the computer operating architecture for future general aviation controls and displays was identified. Displays and communication hardware were integrated in the testbed. The NDE processes were validated for use in certifying manufacturing of small composite components. Icing protection system design guidelines for safe operation of general aviation aircraft were developed. In early FY 1996, a comprehensive flight acoustics database was acquired for the XV-15 civil tiltrotor, including conventional and steep approach paths. This flight database of ground noise footprints was used to develop low noise approach profiles that provide a 6- dBA reduction over conventional approaches, and will be used as inputs to the Vertiport Noise Impact model. An investigation of low-noise flight procedures began in the vertical motion simulator, and contingency engine power concepts were selected for preliminary design.

In FY 1997. the transportation systems operational, functional and performance requirements for general aviation aircraft will be defined and published for users, aircraft and infrastructure. The noise reduction provided by the low-noise proprietor concepts will be evaluated through wind tunnel testing and the isolated rotor configuration database will be completed to .validate the blade vortex interaction prediction code. During model scale testing, multiple proprotor concepts, to be developed by several of the U.S. rotorcraft manufacturers, will demonstrate noise reduction of 6 dBA. From this database of rotor tests, concepts will be selected for more extensive full-span testing. The initial evaluation of low-noise approach profiles will be completed in FY 1997.

In FY 1998, system components for general aviation aircraft will be downselected for further evaluation. The best contingency engine civil tiltrotor power concepts will be also be downselected in FY 1998 for more detailed design and further analysis.

## Technology Integration & Environmental Impact

In early 1996, a quick-response report server was established on the Internet to provide a single, integrated source of data needed to perform aviation system analyses. The incremental development of the aviation system analysis capability continued with the development of an executive architecture and an economic analysis module. In FY 1997, the first generation Aviation System Analysis Capability (ASAC)will be released. ASAC is envisioned primarily as a process for understanding and evaluating the impact of advanced aviation technologies on the U S . economy. ASAC will consist of a diverse collection of models, data bases, and analysts from both the public and private sectors brought together in varying combinations to work issues of common interest to NASA and other organizations within the aviation community. ASAC will provide this support through information system resources, models and analytical expertise, as well as through its role as a conductor and organizer of large-scale studies of the aviation system and advanced technologies. In FY 1998, the second-generation aviation system analysis capability will be released.

The first program-level assessment report on the atmospheric impact of subsonic aviation was completed in FY 1996. leading to participation by principal investigators in preparation of the 1997 United Nations Environment Program/World Meteorological Organization (UNEP/WMO) ozone assessment report. Data that was analyzed from the first in-situ atmospheric observations were released, and a fundamental study of combustion product interaction will be completed in FY 1997. In FY 1996, the first in-situ atmospheric observations dedicated to subsonic aviation assessment were completed when climate-related measurements were

performed aboard the DC-8 flying laboratory. The second field campaign with the DC-8 flying laboratory made ozone chemistry measurements to characterize sources of reactive nitrogen in frequently traveled regions. In FY 1998, the third DC-8 flying laboratory field campaign will be performed to measure tropical convection.

**Composites**

In FY 1996, the application of composites to commercial transport wings was validated by completing the baseline aircraft and requirements document for composite airframes, identifying candidate materials, and carrying out cost and weight trades and sensitivity studies. In FY 1997, a manufacturing plan for the production of multiple composite components that meet all cost and weight goals, as well as a structural development plan, will be developed. Manufacturing equipment will be fully operational, fabrication and assembly processes will be defined, and manufacturing cost allocations will be revised demonstrating the capability to fabricate and assemble composite wings below the cost of conventional aluminum wings. In FY 1998, a critical design review will be held and component tests will be completed.

Advanced Space
Transportation
Technololgy

SCIENCE. AERONAUTICS. AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

**OFFICE OF AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY**

**ADVANCED SPACE TRANSPORTATION TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Delta Clipper., | 17.000 | -- | -- |
| X-33 Advanced Technology Demonstrator | 157.500 | 246.800 | 333.500 |
| [Stennis Space Center Component Test Facility C of F] | [10,500] | L 1 | [--] |
| [Stennis Space Center Test Stand Refurbishment C of F]. | [--1 | [2,300] | [3,700] |
| X-34 Technology Demonstration Program | 30.000 | 36.700 | 20.000 |
| Advanced Space Transportation Program (ASTP) | 29.500 | 53.200 | 43.100 |
| Total | 234.000 | 336.700 | 396.600 |
| Distribution of Program Amount by Installation | | | |
| Johnson Space Center | 900 | 3.000 | 2.400 |
| Kennedy Space Center | 300 | 100 | 400 |
| Marshall Space Flight Center | 147.600 | 274.200 | 340.800 |
| Stennis Space Center | 46.400 | 6.900 | 10.300 |
| Ames Research Center | 7.700 | 8.600 | 6.800 |
| Dryden Flight Research Center | -- | 6.300 | 2.700 |
| Langley Research Center | 14.300 | 13.200 | 5.700 |
| Lewis Research Center | 2.900 | 2.700 | 3.200 |
| Goddard Space Flight Center | -- | 100 | -- |
| Jet Propulsion Laboratory | 3.300 | 8.700 | 5.600 |
| Headquarters | 10.600 | 12.900 | 18.700 |
| Total | 234.000 | 336.700 | 396.600 |

## ADVANCED SPACE TRANSPORTATION TECHNOLOGY

### PROGRAM GOALS

The goal of the Advanced Space Transportation Office is to develop new technologies aimed at revitalizing access to space. These new technologies are targeted to reduce launch costs dramatically over the next decade, and to increase the safety and reliability of current and next generation launch systems.

### STRATEGY FOR ACHIEVING GOALS

NASA's primary space launch technology 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. This in turn should enable the U.S. to recapture leadership in worldwide commercial space transportation in the early decades of the next century. Consistent with the National Space Transportation Policy, NASA, as a member of the national team, will develop technology for the next generation space transportation system, with a target of reducing launch vehicle development and operations costs dramatically after the year 2000. NASA will also participate with the Department of Defense (DOD) in developing technology to improve the competitive position of existing launch vehicles. In addition, NASA will develop, with industry and academia, advanced technology for subsequent generations of launch systems.

This program is divided into the Reusable Launch Vehicle (RLV) and the Advanced Space Transportation Program (ASTP). Incorporating innovative partnerships with industry and academia, the RLV and ASTP programs will prepare the U.S. for key decisions regarding the future development of space transportation systems. NASA funding for Expendable Launch Vehicle (ELV) cooperative technology improvements ended in FY 1996. However, NASA will continue to support DOD (the lead agency) for ELV improvements in areas where NASA's unique facilities and expertise can help government and industry. Moreover, improvements to launch operations applicable to ELV's are an integral part of the RLV program.

NASA is developing a comprehensive space launch strategic plan outlining the Agency's space launch requirements, the current investments in launch vehicle technology development and operations, and the objectives, strategy, budget and key decisions that will enable a future space transportation architecture for NASA. As part of this effort, the RLV criteria are being updated to reflect the program's progress to date. The plan will be completed before the end of FY 1997.

#### Reusable Launch Vehicle (RLV)

The Reusable Launch Vehicle Flight Program combines business planning and ground-based technology development with a series of flight demonstrators --- the DC-XA, X-34, and X-33. These flight demonstrators incrementally expand the technology and flight

test envelope, provide a realistic environment to prove Reusable Launch Vehicle technologies, and demonstrate operability required for low-cost access to space. The RLV program will also provide the necessary business planning to permit industry and the government to commit to revolutionary new space launch systems beginning at the turn of the century.

Key new technologies have already flown in small-scale flight demonstrations on the advanced version of the Delta Clipper-Experimental (DC-X) flight vehicle, now referred to as the DC-XA or Clipper Graham. For example, the first-ever, large-scale composite liquid hydrogen tank, together with composite fuel lines and valves, was flown on the DC-XA in the spring of 1996. This represented the first major flight demonstration and a significant advance in the use of composites for cryogenic application. DC-XA also provided the first significant demonstration of Industry-Government partnerships through the use of Cooperative Agreements. The DC-XA program was scheduled to end in FY 1996 and completed four of five planned flights prior to a mishap on July 31. Despite the mishap, which was unrelated to the new technologies, the DC-XA provided an important first step for the RLV demonstration program. In FY 1997 and FY 1998 the RLV program will consist of the **X-34** and **X-33** programs (X-33 contains ground and flight technology components).

The **X-34** program will demonstrate technologies necessary for a reusable vehicle, but will not be a commercially viable vehicle itself. This allows the **X-34** to be more effectively designed as a rocket-powered, Mach-8-capable flight demonstrator test bed to close the performance gap between the subsonic DC-XA and the Mach-15-capable **X-33.** The **X-34** objective is to enhance U.S. space launch capabilities through the development and demonstration of key technologies applicable to future, low-cost, reusable launch vehicles. The **X-34,** flying in the first quarter of FY 1999, 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 thousand or less. The **X-34** program is planning to procure two flight articles, a change from the initial plan, but more in keeping with the usual practice in X-vehicle programs; this change will help ensure that the program meets its objectives without constraining the aggressiveness of the demonstration effort.

The 30-month, fixed-price **X-34** contract will be conducted by Orbital Sciences Corp. of Dulles, Virginia. Government involvement will include NASA's Ames, Langley, Dryden, Marshall and White Sands complexes and Holloman Air Force Base. Government tasks cover primary propulsion development activity, thermal protection system integration, wind tunnel support and testing and flight operations.

After completion of the first flight series (the basic contract includes two flights), the **X-34** program is planning a second phase for additional fight testing of up to 25 flights in one year. These flights will demonstrate key embedded technologies and systems operations, as well as additional technology experiments and test articles from the RLV and Advanced Space Transportation programs. **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.

The **X-33** objective is to demonstrate technologies and operations concepts that could reduce space transportation costs to one tenth of their current level, thereby freeing up billions of dollars for technology, science and exploration. As directed in the National Space Transportation Policy, the **X-33** program includes two major decision points. The first, whether or not to proceed

with Phase II, was completed in July 1996 and was made based on specific programmatic, business planning and technical criteria which had previously been agreed upon by NASA, the Office of Management and Budget and the Office of Science and Technology Policy. The second decision will be made after X-33 ground and flight tests, when Government and industry will consider whether private financing of the full-scale development of an operational RLV (Phase III) should be pursued. At that point, if the industry partners, along with the private capital investment community, are not satisfied that the technological risk is low enough to proceed to full-scale development, NASA may continue RLV technology work to accomplish further risk reduction. For example, the X-33 may require further testing, or a vehicle to test alternative technologies may be needed to prove the ultimate feasibility of an RLV.

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 only those tasks which offer the most effective means to accomplish the program's goals. The Government participants report costs and manpower to the industry team leader (Lockheed-Martin Skunkworks, Palmdale, CA) 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 FY 1998 budget proposes multi-year appropriations for development of the X-33. The requested appropriations are $329.8 million in FY 1998, $313.9 million in FY 1999 and $75 million in FY 2000. The enactment of these appropriations will ensure the stability to manage and execute this program within its budget and schedule commitments.

The X-33 is an integrated technology effort to flight-demonstrate key technologies, and deliver advancements in: 1) propulsion, including a prototype engine: 2) lighter, reusable cryogenic tanks: 3) application of New Millennium microelectronics for vastly improved reliability and vehicle health management; 4) advanced Thermal Protection Systems to reduce maintenance: and 5) ground and flight operations techniques that will substantially reduce operations costs for an RLV. 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 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 an unprecedented 50-75 flight tests of key technology demonstration prior to a full-scale development decision.

Innovative programmatic and business requirements for an operational commercial RLV will receive equal consideration with technology demonstrations through the development of industry-led business plans. These plans will address policy and legislative issues and private financing options. 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.

As directed by Congress, the **X-33** program funding includes $10.5 million in Construction of Facilities funding in FY 1996 for completion of the Component Test Facility at Stennis Space Center. The **X-33** program also funds refurbishment of the **B-2** test stand at Stennis in FY 1997 (**$2.3** million) and FY 1998 (**$3.7** million) to enable testing of **X-33** development and flight engines.

## Advanced Space Transportation Program (ASTP)

Continuing the revolutionary advancements in space access that we expect from the RLV Technology Program, ASTP is developing key technologies to dramatically reduce space transportation costs across the mission spectrum. The ASTP will focus on technological advances with the potential to reduce costs beyond RLV goals as well as technology development required to support NASA strategic needs not addressed by RLV. ASTP aims at a cost-to-orbit measured in hundreds, not thousands, of dollars per pound. Major near-term efforts include the Low-Cost Booster Technology (LCBT) project and the Advanced Reusable Transportation Technologies (ARTT) project.

NASA's science enterprises are developing revolutionary new technologies to drive down the size and lifecycle costs of their missions: however, until the initiation of the Low Cost Booster Technology project, there was no corresponding technology development effort for the smaller launchers to be used for these missions. Without the new technologies to be developed and demonstrated by the LCBT project, launch costs for these missions will remain at current levels, and the proportion of mission resources spent on launch costs will become the "long pole in the tent" as the other costs of each mission are driven down over the next decade.

The LCBT project is investing in innovative technologies for low-cost manufacturing and systems engineering to address this problem. The project will lead to space transportation hardware that does not require the highly specialized, labor-intensive manufacturing and operation of current space transportation systems. For example, the current price of an existing, small-launcher liquid oxygen/kerosene engine is **$3-5** million. This program has initiated efforts to drive the costs of such engine systems down to **$300-400** thousand and will begin testing priority technologies by the end of FY 1997. The LCBT program funds will be used to develop these subsystem component technologies, which will be integrated into the flight engine for the **X-34** flight demonstrator. The funds for the development, integration and test of the **X-34** engine system itself, however, have been moved to the **X-34** budget element in FY 1997 and FY 1998. The **X-34** flight test program is to begin in the first quarter of FY 1999, and it is anticipated that advanced new engine component technologies will continue to be developed by the LCBT program and integrated into the **X-34** propulsion system for demonstration throughout its flight program.

The LCBT project has selected nine companies to perform fifteen component development activities as the first phase of the program. These technologies will run in parallel with the **X-34** engine development and will be focused on operationally efficient, low-cost hardware at the component and subsystem level. These activities were selected under a NASA Research Announcement (NRA) released in the Spring of 1996. A second program phase is being considered as part of the space launch strategic planning efforts which will be completed before the end of FY 1997. Inclusion of a second LCBT phase will depend, in large part, on programmatic and technical progress during FY 1997, and on the availability of funds. To prepare for a second phase decision, NASA will solicit industry proposals for an integrated development and flight demonstration program, to include a business plan, customer analysis, concept definition and technology plan for a new small booster. It is anticipated that a demonstration effort, if

initiated, would be managed as part of the RLV flight demonstration program. The results of this second phase would be intended to support a NASA decision on whether or not to proceed with a procurement of commercial launch services utilizing such an advanced small booster for the University Explorer- (UNEX-)class science payloads. While the UNEX-class boosters represent the first application of these important technologies, it is expected that the advancements will apply to other low-cost reusable liquid booster concepts (e.g., flyback boosters).

The Hybrid Propulsion Demonstration Program (HPDP).begun under a separate project in FY 1995, contributes to the goals of the LCBT project, and thus has been incorporated into the new effort. The HPDP is being conducted under a Cooperative Agreement between NASA, DOD and U.S. industry, with the objective of demonstrating hybrid (solid fuel, liquid oxidizer) propulsion technology to enable U S . industry to commercialize hybrid boosters for space launch operations. Hybrid motors offer potential for safer, lower cost, and environmentally friendlier boosters for U.S. launch providers. This resource-shared (experts, facilities and dollars) and jointly managed program has already successfully demonstrated small sounding rocket motors, and will soon demonstrate full-size, flight-like boosters. The completion of the HPDP in FY 1999 is designed to allow rapid development of flight hardware with minimum risk, on a schedule supportive of the other elements of the LCBT project.

The Advanced Reusable Transportation Technologies (ARTT) project will target technologies with a goal of a factor of one hundred reduction in current medium-to-large payload launch costs. The early focus of this effort is on rocket-based combined cycle (RBCC) propulsion systems. Four RBCC concepts have been selected for preliminary proof-of-concept ground demonstration in late FY 1997. These demonstrations will lead to a decision in FY 1998 on whether or not to proceed with further development and a flight demonstration project. Technologies will be addressed in partnership with NASA Aeronautics Centers and industry to assure maximum synergy between hypersonic research and the systems design and application to space launch. ARTT also includes a focused advanced materials and TPS activity to develop launch system structures and materials technologies.

The ASTP program also contains funding for the In-Space Transportation project and the Engineering Capability Development effort. In-Space Transportation is a joint effort with the Office of Space Science to support development of advanced spacecraft propulsion systems at Lewis Research Center and the Jet Propulsion Lab. The major project is currently the NSTAR ion propulsion system to be used on the New Millennium Deep Space-1 mission. The Engineering Capability Development budget element supports the Ames Research Center's arcjet facility to enable thermal protection system testing, as well as the development and maintenance of system analytical design tools at Ames and Langley Research Centers.

## MEASURES OF PERFORMANCE

### Reusable Launch Vehicle (RLV)

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| X-33 Phase II Design, Development and Flight Test Approval/Awarded<br>Plan: July 1996<br>Actual: July 1996 | OSTP/OMB detailed decision criteria accomplished, approval granted and award made. |

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|---|---|
| **X-33** System Requirements Review<br>Plan: August 1996<br>Actual: August 1996 | **X-33** requirements established and approved. |
| **X-33** Vehicle Systems Preliminary Design Review<br>Plan: November 1996<br>Actual: November 1996 | Systems preliminary design review was accomplished for the **X-33** vehicle, the first key review milestone. |
| **X-33** Environmental Impact Statement Hearings<br>Plan: November 1996<br>Actual: November 1996 | Public Hearings as part of Environmental Impact Statement process are required to address **X-33** launch and landing site environmental and overtlight issues. |
| LH2 and LO2 Tank Delivery<br>Plan: **4th** Qtr FY 1997 | Completes design, manufacture, test and delivery. |
| **X-33** CDR<br>Plan: July - August 1997 | The second key review milestone, which will close the vehicle design for production, validate readiness of the vehicle technologies, and measure schedule to first flight. |
| First Aerospike Engine Test<br>Plan: February 1998 | First complete J2-Aerospike test to support first flight unit engine scheduled for delivery in July 1998. |
| **X-33** Thermal Protection System Delivery<br>Plan: April 1998 | Delivery of complete Thermal Protection System for **X-33** flight demonstrator. |
| **X-33** Vehicle Rollout<br>Plan: September 1998 | **X-33** flight demonstrator vehicle rollout enabling final checkout. |
| **X-33** First Flight<br>Plan: March 1999 | The flight program, based at Dryden Flight Research Center, will start with relatively low-speed flights (approximately Mach **3)** and then expand the flight envelope and vehicle velocity to Mach 15 as confidence is gained in **X-33** system performance. |

## Advanced Space Transportation Program (ASTP)

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|---|---|
| Complete ASTP technology road maps and publish final plan.<br>Plan: March 1996<br>Actual: March 1996 | Completed on schedule. |
| NASA Research Announcements (NRA) released for Low-Cost Booster (LCBT)<br>Plan: April 1996<br>Actual: April 1996 | Proposals were sought for innovative technologies to enable significant launch cost reductions. Nine proposals for 15 tasks were selected for award. Two proposals from the same company were combined. |
| Authority to Proceed on LCBT first cycle proposal responses<br>Plan: September 1996<br>Actual: January 1997 | One contract awarded October 1996<br>Three contracts awarded December 1996<br>Three contracts awarded January 1997 |
| Launch first hybrid sounding rocket from Wallops Flight Facility<br>Plan: December 1996<br>Actual: December 1996 | Represents the first in a series of hybrid rocket flights conducted or sponsored by Environmental Aeroscience Corporation (EAC). Fixed-price milestone payment depended on flight occurring on schedule. |
| Ground Test First Hybrid 250K Motor<br>Plan: 2nd Qtr FY 1997 | Fixed-price milestone payment depends on test occurring on schedule. |
| NSTAR 8000 Hour Ground Test Completion<br>Plan: July 1997 | Demonstrate life of NSTAR Engine consistent with duty cycle on New Millennium Deep Space I. Test underway with no issues to date. |
| NSTAR delivery for DS-1 launch<br>Plan: August 1997 | Delivery of flight hardware will ensure adequate time for checkout and integration into the New Millennium spacecraft. |

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| Rocket-based combined cycle (RBCC) inlet and ejector/ combustor (Mach 0-4) test completion<br>Plan: December 1997 | Ground test of critical low-speed RBCC technologies such as inlet design and low-speed air augmentation. |
| Deliver X-34 test flight engine to RLV X-34 project<br>Plan: June 1998 | Supports LOX/RP flight demonstration on RLV X-34 vehicle in September 1998. |

## ACCOMPLISHMENTS AND PLANS

### Reusable Launch Vehicle (RLV)

The DC-XA completed integration and checkout of new, upgraded components in the second quarter, and initiated flight testing in May. The DC-XA completed four test flights but experienced a landing gear failure on flight four and the vehicle was destroyed. The new RLV technologies integrated into DC-XA performed extremely well and successfully completed the first step of the RLV technology program.

The initial X-34 effort combined NASA's need for early technology demonstration with industry's need for a commercially viable small launcher. Unfortunately, our industry partners determined that the current economic viability of the program could not justify their investment and they withdrew. However, NASA's need for the X-34 technology demonstrator remained, and an X-34 NASA Research Announcement was released in the second quarter of FY 1996. The 30-month, fixed-price $60M contract was awarded to OSC in July 1996 for the basic vehicle demonstration program and two flights. The X-34 engine is to be furnished by NASA, and its development and fabrication costs are not included in the OSC contract; nevertheless, the funding for the X-34 engine system development and integration work has now been moved from the ASTP budget element to the X-34 budget line in FY 1997-98.

The RLV program completed demonstrations of technologies critical to meeting the criteria for the 1996 X-33 flight demonstrator (Phase 11) decision. The data base on candidate RLV systems/subsystems was expanded significantly with new test results on advanced, low-cost propulsion systems: reusable, light-weight cryogenic tanks and structures; light-weight and low-maintenance thermal protection systems: and vehicle health monitoring and maintenance systems within a highly operable vehicle system.

The decision to proceed with X-33 Phase II was made only after the program underwent an extraordinary amount of independent, external scrutiny and review. An extensive, independent study was completed by a panel of the National Research Council's Aeronautics and Space Engineering Board (ASEB) validating the X-33 development, test, and analysis programs in reaching the Phase II decision milestone. Also, the NASA Advisory Committee, tasked with an independent verification of the criteria,

determined that the criteria had been met and recommended proceeding with development of the **X-33.** Moreover, the **X-33** program underwent a NASA Non-Advocate Review (NAR), which also recommended going ahead with Phase II.

Three **X-33** industry teams submitted their proposals for Phase II in the third quarter of FY 1996. The evaluation team selected Lockheed Martin Skunkworks and Phase II activities commenced July 2, 1996, following Administration approval.

The Lockheed Martin **X-33** program consists of significant ground technology and flight demonstration of key RLV technologies, including an innovative aerospike propulsion system, metallic thermal protection systems and light-weight, robust, composite cryogenic tanks in an efficient lifting-body design. Operational goals of the vehicle are to: eliminate re-certification between flights; significantly reduce turnaround inspections; eliminate engine gimbals and flex lines to reduce reflight maintenance and operations: provide engine-out capability with return to launch site: and improve operability by incorporating modular components that are accessible without removal.

FY 1997 is a critical year for the **X-34.** The project team will conduct all major technology development work, and will complete design of the test vehicle's thermal protection, main engine propulsion, and avionics and control systems. L-1011 launch platform modifications and preliminary airframe integration will also be done. System design freeze and associated reviews will be conducted in the third quarter of FY 1997 in anticipation of first flight in the first quarter of FY 1999.

**X-33** Preliminary Design Review (PDR) was completed in November 1996 and represented the first critical milestone regarding technology maturity and schedule to first flight. Subsequent **X-33** program activities in FY 1997 will focus on flight vehicle design and development and on a comprehensive ground test program emphasizing a full-scale RLV prototype engine and lightweight composite hydrogen and oxygen tanks. The **X-33** linear aerospike engine, main propulsion system, liquid oxygen tank, hydrogen tank and reaction control system (RCS) Critical Design Reviews (CDR) will be completed during the second quarter. The standoff structure CDR and release of the draft Environmental Impact Statement (EIS) will be finished during the third quarter. The Thermal Protection System (TPS), subsystems and software, and the ground systems and operations CDRs will be completed during the fourth quarter. These CDRs represent the most critical milestones regarding technology maturity and schedule to first flight (scheduled for FY 1999). The final EIS including the record of decision will be completed by the end of FY 1997. **X-33** integration, assembly and test tooling buildup will be initiated. RLV efforts will also include system definition and business planning efforts required to support private sector and government investment options for the Phase III decision.

FY 1997 Funding includes **$2.3** million in CoF funds for test stand modifications at the Stennis Space Center. These modifications are required to allow testing of **X-33** development and fight engines.

The FY 1998 **X-34** effort will primarily be focused on final airframe integration, technology experiment development, pre-flight testing and final engine checkout. The basic **X-34** contract will in essence be completed, with the exception of the first two flight tests, which will be conducted in the first quarter of FY 1999. Up to **25** flights per year will be performed under an option to the contract in FY 1999 after completion of the basic contact.

X-33 FY 1998 program activities will continue effort of FY 1997 and focus on flight vehicle design and development and on the comprehensive ground test program. The liquid oxygen and liquid hydrogen tanks will be delivered during the first quarter, with other hardware deliveries scheduled through the year. The X-33 linear aerospike engine testing will begin late in the second quarter. X-33 flight vehicle integration and final assembly will be initiated in anticipation of X-33 rollout early in FY 1999. The PDR for the RLV prototype engine (YRS-2200) will be completed during the second quarter in anticipation of the CDR early in FY 1999. RLV efforts in FY 1998 will also continue system definition and business planning efforts in preparation for the Phase III decision.

FY 1998 funding includes $3.7 million in CoF funds for test stand modifications at the Stennis Space Center. These modifications are required to allow testing of X-33 development and flight engines.

**Advanced Space Transportation Program (ASTP)**

A NASA Research Announcement (NRA) for Low-Cost Booster Technologies (LCBT) components was released in April 1996, resulting in thirty-four first-cycle and 14 second-cycle proposals submitted for evaluation. Seven first-cycle proposals and two second-cycle proposals were selected for award, with the first agreement signed in October 1996, and the rest to be signed by January 1997. Substantial resources were invested in the LOX/RP Propulsion Test Article (PTA) which will support ground testing of both the X-34 engine and components from the NRA. A preliminary requirements review (PRR) on the PTA was completed in June 1996, the preliminary design review (PDR) was done in August, and critical design review (CDR) was completed in December. A RFP for procurement of the testbed engine, including the X-34 engine, was completed in August. All X-34 engine system development, integration and procurement funding is moved to the X-34 budget element in FY 1997-98, although advanced component technologies will continue to be funded in the LCBT project.

A NASA Research Announcement for Advanced Reusable Transportation Technologies (ARTT) was released in April 1996. Five contracts have been awarded for the definition of rocket-based combined cycle (RBCC) conceptual vehicle design approaches, ground testing of components and engine concepts, and proof-of-concept design definition. Efforts have also been initiated to develop an Advanced Structures and TPS Technology Plan focused on the development of generic technologies related to primary structure, cryotank structure and thermal protection systems.

Consolidation of propulsion testing activities was initiated at the Stennis component test facility in FY 1996 for $45.5 million, including $10.5 million of CoF funds. This investment will complete the facility originally intended to be used by the Space Transportation Main Engine, and will provide a state-of-the-art capability to test rocket engine components and subsystems for the RLV and ASTP programs.

In FY 1997, LCBT efforts will focus on continuing the work under the NRAs, in order to develop and demonstrate these technologies to the level required for industry to consider them viable for inclusion in their proposals for Phase II of the LCBT project -- the integrated flight demonstration phase. Multiple industry-led studies will be conducted to address the business and technology needs of a small, low-cost booster. Initiation of Phase II is dependent on the outcome of the space launch strategic

planning effort, on overall LCBT program progress, on the results of the industry-led studies and on the availability of funds. It is anticipated that, if initiated, Phase II would be managed as part of the RLV flight demonstration program.

Advanced Reusable Transportation Technologies contractors will complete their individual concept definition reviews and initiate ground testing of RBCC Mach 0 - 4 test hardware in FY 1997. Testing of critical component technologies will be in progress.

The Hybrid Propulsion Development Program (HPDP) will complete most of the smaller component development testing and database generation, and will conduct extensive demonstration tests of large, 250,000-pound-thrust motors in FY 1997. Several sounding rocket flight demonstrations will be conducted.

Engineering Capability development will continue to fund utilization, maintenance, and productivity upgrades for the premiere national facilities at LaRC and ARC required to accomplish the goals of the Advanced Space Transportation programs.

FY 1998 LCBT funding supports extensive component testing of technologies developed under the Phase I NRAs, with the goal of upgrading the X-34 engine using these components, and then possibly flight-demonstrating them using the X-34. Initiation of LCBT Phase II will depend on the outcome of the space launch strategic planning effort, on overall LCBT program progress and on the availability of funds.

Also in FY 1998, Advanced Reusable Transportation Technologies contractors will demonstrate, on the ground, higher Mach operation into the ramjet and scramjet operating modes, as well as transition between operating modes.

NSTAR ion propulsion system launch on New Millennium DS I is scheduled for the third quarter of FY 1998. Subsystem level integration and testing will be conducted during FY 1998 for a Solar Thermal upper stage flight experiment.

The FY 1998 Hybrid program will continue testing 250,000-pound-thrust motors, including flight-like motors. Engineering Capability development will also continue to be supported.

Commercial
Technology
Programs

**SCIENCE. AERONAUTICS AND TECHNOLOGY**

**FISCAL YEAR 1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY** **COMMERCIAL TECHNOLOGY/SBIR**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Commercial Technology Programs | 27.400 | 25.800 | 20.000 | SAT 4.3-2 |
| Technology Transfer Agents | 17.100 | 7.800 | 7.800 | SAT 4.3-6 |
| Small Business Innovation Research Programs | 125.700 | 125.000 | 125.000 | SAT 4.3-10 |
| Total | 170.200 | 158.600 | 158.0 0 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | 24.300 | 17.800 | 17.600 | |
| Kennedy Space Center | 5.700 | 6.500 | 6.800 | |
| Marshall Space Flight Center | 23.200 | 30.900 | 34.900 | |
| Stennis Space Center | 4.000 | 4. 100 | 4.400 | |
| Ames Research Center | 14.100 | 15.600 | 15.100 | |
| Dryden Flight Research Center | 4.800 | 4.300 | 4.800 | |
| Langley Research Center | 20.500 | 20.700 | 18,600 | |
| Lewis Research Center | 20.300 | 22. 100 | 19.500 | |
| Goddard Space Flight Center | 29.500 | 27.000 | 25.900 | |
| Jet Propulsion Laboratory | 2.800 | 2.200 | 1.700 | |
| Headquarters | 21.000 | 7.400 | 3.500 | |
| Total | 170.200 | 158.600 | 152.800 | |

BASIS OF FY 1998 FUNDING REQUIREMENT

## COMMERCIAL E( A

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Technology Dissemination & Marketing | 6,400 | 6,900 | 3,100 |
| Electronic Network | 700 | 800 | 900 |
| Business Practices Implementation | 17,600 | 15,800 | 14,600 |
| Policy, Metrics. & Evaluation.. | 2,000 | 1,800 | 900 |
| Culture Change & Education | 700 | 500 | 500 |
| Total | 27.400 | 25,800 | 20,000 |

## PROGRAM GOALS

The commercial technology program goal is to share the harvest of NASA's technology programs with the U.S. industrial community. The goal encompasses the commercialization of technology developed in all the Agency's Enterprises, in past as well as current programs. The scope of the commercialization effort includes technologies created at NASA centers by civil servants and innovations from NASA contractors. The technology commercialization program assures that NASA's technology developments contribute to a significant improvement in the quality of American life and an increase in America's international competitiveness.

## STRATEGY FOR ACHIEVING GOALS

NASA is continuing to implement a new way of doing business in the area of technology transfer. Changes in national R&D investment guidelines have elevated commercial technology transfer to a fundamental NASA mission. NASA's Agenda for Change, approved by Administrator Goldin in July 1994, is the agency's blueprint for achieving this mission. The Agenda for Change is organized into six sections, each reflecting an important aspect of this new way of doing business. The six sections are: Commercial Technology Policy: Commercial Technology Business Practices: Marketing NASA's Capabilities: Commercial Technology Metrics: Culture Change Through Training and Education: and the Commercial Technology Electronic Network. Each section implements components of the national and agency policies in order to reinvent the way that NASA transfers technology to and from the national economy.

Two elements of the Agenda for Change are particularly important for the overall goal to be reached. The first element involves the establishment of metrics which allow program managers to determine the success rate of the various strategies. Four categories of metrics now exist, including inventory, technology, partnership, and success story metrics. The other element is the creation and maintenance of a new information network for commercial technology transfer. This network is now fully operational and accessible to the public via the Internet, and includes all current, non-sensitive technology activities and opportunities. To succeed, the commercial technology mission must become a responsibility of every NASA employee, contractor and industry and academic partner. The Agenda for Change marks the beginning **of** NASA's new focus, management commitment, and employee empowerment to improve our contributions to America's economic security through the pursuit of our aeronautics and space missions. All NASA program offices and field centers are beginning to invest appropriately in technology commercialization efforts, and NASA has adopted a near-term target of investing 10-20 percent of the agency's R&D budget in commercial partnerships with industry by the end of FY 2000

## MEASURES OF PERFORMANCE

| | |
|---|---|
| Implement a detailed general targeted marketing strategy<br>Plan; October 1995<br>Actual: February 1996 | Marketing NASA technology and capabilities to industry is critical to NASA's ability to form partnerships with the private sector. **A** general and targeted marketing campaign will make it possible to understand industry's R&D requirements and identify where the synergies **of** NASA and industry technology partnerships can be most beneficial. |
| Complete Inventory of 100% of NASA technologies<br>Plan: September 1996<br>Actual: April 1996 | The inventory **of** all NASA technologies provides an agency-wide perspective on available NASA technologies and facilitates finding potential partners for commercial ventures. |
| Complete documentation that 10% of NASA's R&D budget is in commercial partnerships with industry.<br>Plan: September 1996<br>Actual: September 1996 | Successfully reaching 10% meets the lower range of National Performance Review goal for the agency. |
| Establish Internet-based access to the NASA commercial technology database.<br>Plan: September 1996<br>Actual: April 1996 | Internet access will provide searchable industry and public archives and increase the effectiveness of technology transfer. |

| | |
|---|---|
| Increase the percentage of NASA R&D Invested in Commercial Partnerships with a goal of achieving 15%.<br>Plan: October 1997 | Showing steady improvement toward reaching 20% will provide assurance that we can meet the upper range of the National Performance Review goal for the agency. |
| Inventory all new technology from new contracts initiated in FY 1997<br>Plan: December 1997 | Keep technology archives updated to maintain maximum relevance to private sector. |
| Expand training program for NASA R&D program managers.<br>Plan: April 1998 | Expanded training should help foster the agency's internal culture change necessary to increase technology transfer and partnerships with private industry. |
| Assess approximately 100% of NASA technology for commercial application.<br>Plan: December 1998 | Current inventory of technology will be reviewed, assessed and rated for commercial potential. |

## ACCOMPLISHMENTS AND PLANS

In FY 1996, particular focus was on achieving the goal of investing 10 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, as well as strengthening the international competitiveness of key industry sectors. FY 1996 efforts also included the initiation and demonstration of an automated, on-line, metrics collection system and technology transfer success story database (TechTracS) for customer and stakeholder use. Another key activity in FY 1996 was the initiation of an Internet-based electronic network to integrate and support NASA's technology commercialization operations throughout the U.S. This network draws upon the TechTracS system and provides U.S. industry and research organizations with electronic access to information and databases which highlight available NASA technologies, technical expertise and facilities. A professional training course on commercial technology was also initiated as part of the agency's program managers' training program, which focuses on increasing both technology transfer and business partnerships between NASA and the private sector.

In FY 1997 and 1998 the emphasis will be on increasing commercial partnerships with industry and continuing refinement of the technology and partnership database, updating it to include new agency contracting efforts and to describe new technologies that

are to be made public on the electronic network. The agency's goal for these years will be to increase the percentage of the **NASA** R&D budget in commercial partnerships with industry to 15 percent. In FY 1997 and **1998. NASA** will also continue to utilize and improve the Internet as an electronic marketplace for **NASA** technology assets, facilitating technology transfer and commercialization opportunities between U.S. industry and **NASA.** In addition, a series of training opportunities focused on the commercial technology strategy and its implementation actions will be expanded within **NASA's** standard program management professional training program.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### TECHNOLOGY TRANSFER AGENTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| National Technology Transfer Center | 7,500 | 7,800 | 7,800 |
| ADANET Project | 2,100 | -- | -- |
| Rural State Technology Transfer Center | 4,500 | -- | -- |
| Commercial Spaceport Activities | 3,000 | -- | -- |
| Total | 17,100 | 7,800 | 7,800 |

## PROGRAM GOALS

The goal of technology transfer agents, such as the National Technology Transfer Center (NTTC), is to facilitate the transfer and commercial use of federally-sponsored research and technology (and associated capabilities) to the U.S. private sector. The increased use of this research and technology will enhance U.S. economic growth and industrial competitiveness.

## STRATEGY FOR ACHIEVING GOALS

Since 1990, the NTTC, managed by Wheeling Jesuit College in West Virginia, has served the federal government as a national technology transfer and commercialization resource center. It has been funded since 1990 through a NASA cooperative agreement, with this agreement serving all federal agencies. NASA's comprehensive review of the NTTC in FY 1996 established new roles, objectives and guidance for the NASA-supported operations of the NTTC, bringing its activities closely in line with NASA's Agenda for Change.

In furthering the goals of the Agenda for Change and other supporting federal agencies, the NTTC performs four core roles: (1) to serve as a national gateway for federal technology transfer and commercialization, assisting U.S. industry to locate and access federally-sponsored technology resources and sources of technical/business assistance; (2) to develop, integrate and utilize national databases to enable efficient access to federally-funded research and technology resources: (3) to develop and deliver professional-level training in technology transfer and commercialization for federal agencies and other public and private sector audiences: and (4) to promote U.S. industry awareness of federal-sponsored research and technology resources, as well as opportunities and methods for technology transfer and commercialization.

**MEASURES OF PERFORMANCE**

| | |
|---|---|
| Increase Utilization of NTTC.<br>Plan: October 1996<br>Actual: October 1996 | Process 15,000 information and technical requests from U.S. industry to NTTC for the fiscal year. Process in place in FY 1997 to maintain this level **of** support at minimum. |
| Provide 6000 annual referrals through NTTC to Government-funded technology/business sources.<br>Plan: October 1996<br>Actual: October 1996 | Fully processed requests result in qualified referrals to NASA field centers, other Federally-sponsored research and technology resources, or Federal/State sources of technical/business assistance. Process in place in FY 1997 to maintain this level of support at minimum. |
| Assess NTTC cost effectiveness<br>Plan: October 1996<br>Actual: October 1996 | NTTC will track the average cost/benefit ratio for technical requests processed by the Gateway service to assess cost effectiveness relative to prior years and to other relevant benchmarks. Effectiveness in future will be measured by NTTC's performance in Marketing, Practices, Electronic Network, Metrics and Training program areas, as defined in 1997 operating plan. |
| Increase by 25% Federally-funded research and technology information available via the Internet/World Wide Web.<br>Plan: October 1996<br>Actual: July 1996 | N'ITC will increase public access to Federal research and technology information. Goal accomplished with the implementation of "NASA TechTracS" plus maintenance of "Business Gold - both on the World Wide Web. |
| Establish annual "ITC plan.<br>Plan: November 1996<br>Actual: December 1996 | By November 1 each year, establish an operating plan incorporating NASA guidance and direction. In FY 1997, annual plan was restructured to reflect clearer partnership responsibilities. |
| Transition NTTC training services to full cost-recovery.<br>Plan: September 1997<br>Actual: October 1996 | "ITC is to transition during FY 1997 to full cost recovery for on-going training services and programs provided to private and public sector audiences. Goal accomplished for private training. NASA now pays only for the training it receives. |
| In partnership with NASA, implement six national conferences, including Tech 2007<br>Plan: September 1998 | Furthers the Agenda for Change goal of marketing NASA's capabilities. Follow-on technology symposiums to the Tech 2007 are also to be supported. |

| | |
|---|---|
| In partnership with NASA, target specific industries and companies who may benefit from NASA technology and develop marketing strategies to those industries and firms.<br>Plan: September 1998 | Supports the Agenda for Change goal of marketing NASA's capabilities. |
| In partnership with NASA, expand and deliver the Technology Transfer & Commercialization training course as part of NASA's PPMI.<br>Plan: September 1998 | Supports the Agenda for Change goal of fostering an internal agency culture change through training and education. Course has now been developed, and is to be delivered on a recurring basis. |
| In partnership with NASA, develop and deliver a professional training program for US industry.<br>Plan: September 1998 | The goal of this training will be to better enable companies to successfully commercialize NASA technology. |

## ACCOMPLISHMENTS AND PLANS

The NTTC gateway service produces qualified referrals to federal laboratories and other federally sponsored sources of technology and assistance throughout the nation. The gateway includes telephone calls to the NTTC 1-800 number, Techfinder requests via e-mail, and TechBrief magazine reader request cards. Organizations receiving referrals include NASA, Environmental Protection Agency, Department of Commerce, Department of Energy, Department of Defense, Department of Agriculture, and R&D universities. In support of its gateway and Internet services, the NTTC continues to develop and integrate a unique collection of databases.

In the area of professional training, a unique two-day training course was developed in FY 1996 and is now offered by the NTTC in partnership with NASA, targeting NASA managers and staff. This course has been tied to NASA's Program/Project Management Initiative training, and addresses commercial development and technology transfer issues, as well as procedures to encourage and empower individual responsibility for technology transfer. In addition, the NTTC has continued outreach activities with NASA, the

Federal Laboratory Consortium for Technology Transfer, and other federal agencies to increase U.S. industry awareness of federal technology transfer resources and opportunities.

The ADANET program has been a successful effort in software reuse. It was completed in FY **1996,** with no further funding requirements. During FY **1996,** in conformance with Congressional direction, NASA initiated a cooperative agreement with the Montana State University (MSU) to establish a Rural Technology Transfer & Commercialization Center. This Center will use the funds provided over a period of **4 1/2** years, and will provide services focused on the upper plains state region's core industries (agriculture, timber and mining) and small technology-based business enterprises. Also in conformance with Congressional direction, NASA initiated a grant program in FY **1996** for the development of state-sponsored commercial spaceport business plans and the construction or modification of commercial spaceport infrastructure. No further NASA funding is required for this activity. After FY **1996,** funding within the Technology Transfer Agents program is requested only for the NTTC.

BASIS OF FY 1998 FUNDING REQUIREMENT

## SMALL BUSINESS ATION RESEARCH

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Small Business Innovative Research.. ..... | 125,700 | 125,000 | 125,000 |

**PROGRAM GOALS**

The goals of NASA's Small Business programs are to promote the widest possible award of NASA research contracts to the small business community and to facilitate commercialization of these by the small business community of the results of this research.

**STRATEGY D ACHIEVING AI**

Established by Congress, 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 desirability of a proposed innovation. Selected competitively, Phase I contracts last for 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 lasting up to two years. In general, about 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. The financial resources cannot come from SBIR funds. Private sector investment in various forms is the usual source of Phase III funding.

The NASA SBIR solicitation has 15 major topic areas, which are divided into 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 2200 or more individual proposals each year. Proposals are evaluated by the NASA field centers for scientific and technical merit, key staff qualifications, soundness of the work plan and anticipated commercial benefits. NASA Headquarters (HQ) program offices provide additional insight into commercial applications, program balance, and critical Agency requirements. Selections are made by NASA HQ based upon these recommendations and other considerations. Typically about 400 Phase I awards are selected each year.

In addition to an extensive on-line database regarding the program, NASA also provides information for public access via a bulletin board service and Internet servers. Moreover, NASA has begun to use information technology for the process of developing the technical sub-topics in the solicitation, for the public release of the solicitation in electronic formats and for proposal evaluation. The end-to-end electronic solicitation process is serving as a prototype not only within NASA, but across the government.

Several other innovations have been introduced or strengthened this past year in the small business programs. A detailed, external evaluation of each proposal's ultimate commercial potential is now included in the selection process. In addition, a comprehensive, systematic review of past SBIR projects' post-Phase II, commercial and or mission applications has been initiated. The information from the review will be used to identify critical predictors of commercial viability and, therefore, to increase the effectiveness of the programs. Finally, a new approach is being continued and strengthened to focus several subtopics into specific NASA mission applications. The intent is to more closely tie the SBIR activity to the primary mission needs of each NASA enterprise. The pathfinder for this program has been a collection of subtopics in the general aviation program.

The NASA SBIR program has contributed to the U.S. economy by fostering the establishment and growth of over 1100 small, high-technology businesses. At least 225 private ventures have been initiated based on NASA SBIR programs. Twenty major participants have produced more than $150 million in new revenues.

**MEASURES OF PERFORMANCE**

| | |
|---|---|
| Select and announce new SBIR Phase I awards resulting from the FY 1995 solicitation.<br>Plan: October 1995<br>Actual: October 1995 | Meets the requirements of public law. |
| Select and announce new SBIR Phase II awards resulting from the FY 1995 solicitation.<br>Plan: November 1995<br>Actual: November 1995 | Meets the requirements of public law. |
| Complete development and issue the FY 1996 STTR solicitation.<br>Plan: January 1996<br>Actual: January 1996 | Necessary to ensure the success of the FY 1996 research program. |

| | |
|---|---|
| Compile commercialization metrics from 30% of previous Phase II awardees.<br>Plan: February 1996<br>Actual: April 1996 | Data collected on the Phase II awardees from the previous two years will improve knowledge of the success **of** the program in actually commercializing technology. |
| Select and announce new STTR Phase I awards resulting from the FY 1996 solicitation<br>Plan: May 1996<br>Actual: May 1996 | Meets the requirements of public law |
| Complete development and issue the FY 1996 SBIR solicitation.<br>Plan: June 1996<br>Actual: June 1996 | Necessary to ensure the success of the FY 1996 research program |
| Select and announce new SBIR Phase I awards resulting from the FY 1996 solicitation<br>Plan: December 1996<br>Revised: January 1997 | Initiates awards for new solicitation. |
| Complete development and issue the FY 1997 SBIR solicitation.<br>Plan: April 1997 | Necessary to ensure the success of the FY 1997 research program. |
| Select and announce new SBIR Phase I awards resulting from the FY 1997 solicitation.<br>Plan: August 1997 | Initiates awards for new solicitation. |
| Select and announce new SBIR Phase II awards resulting from the FY 1996 solicitation.<br>Plan: December 1997 | Initiates the follow-on awards resulting from prior Phase I results. |

| | |
|---|---|
| Complete development and issue the FY 1998 SBIR solicitation.<br>Plan: April 1998 | Necessary to ensure the success of the FY 1997 research program. |
| Select and announce new SBIR Phase II awards resulting from the FY 1997 solicitation.<br>Plan: September 1998 | Initiates the follow-on awards resulting from prior Phase I results. |
| Select and announce new SBIR Phase I awards resulting from the FY 1998 solicitation.<br>Plan: September 1998 | Initiates awards for new solicitation. |

## ACCOMPLISHMENTS AND PLANS

At the end of FY 1996, a paperless electronic process for SBIR proposal information management systems was created. Our electronic management system has resulted in steady improvements in program implementation efficiency.

FY 1997 and 1998 will include new SBIR Phase I and Phase II awards, and continued emphasis on and evaluation of commercial successes and successful applications to NASA programs. By February 1997, 1995 Solicitation Phase II awards and 1996 Solicitation Phase I awards will be awarded and under contract or in contract negotiation. In FY 1998, announcements will be made for the 1996 Solicitation Phase II awards and the 1997 Phase I awards.

Mission
Communication
Services

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

**OFFICE OF SPACE FLIGHT** **MISSION COMMUNICATIONS SERVICE**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Ground Networks | 259,500 | 245,600 | 224,700 | SAT 5-4 |
| Mission Control and Data Systems | 162,800 | 147,100 | 145,000 | SAT 5-10 |
| Space Network Customer Service | 27,200 | 25,900 | 31,100 | SAT 5-18 |
| Total | 449,500 | 418,600 | 400,800 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | - | 8,200 | -- | |
| Marshall Space Flight Center | 3,000 | 1,300 | 2,100 | |
| Dryden Space Flight Center | 13,900 | 15,000 | 14,500 | |
| Lewis Research Center | 10,100 | 9,800 | 10,000 | |
| Goddard Space Flight Center | 228,515 | 194,800 | 202,800 | |
| Jet Propulsion Laboratory, | 190,172 | 185,700 | 169,000 | |
| Headquarters | 3,813 | 3,800 | 2,400 | |
| To | 449,500 | 418,600 | 400,800 | |

**PROGRAM GO——**

The Space Communications goal is to enable the conduct of the NASA strategic enterprises by providing telecommunications systems and services. 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 National Space Policy stipulates that NASA will "seek to privatize or commercialize its space communications operations no later than 2005". The Space Operations Management Office **(SOMO),** located at the Johnson Space Center, manages the telecommunication, 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 Mission Communications Services are 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, Earth-orbital, research aircraft, and sub-orbital missions. 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. Radio spectrum management and data standards coordination for NASA are conducted under this program.

## STRATEGY FOR ACHIEVING GOALS

The Space Communications program provides command, tracking and telemetry data services between the ground facilities and flight mission vehicles and 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 for selected missions. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises.

The range of telecommunications systems and services are provided to conduct mission operations, enable tracking, telemetry, and command of spacecraft and sub-orbital aeronautical and balloon research flights. Additionally, services and systems are provided to facilitate data capture, data processing, and data delivery for scientific analysis. The program also provides the high speed computer networking, voice and video conferencing, fax, and other electronic mail services necessary to administer NASA programs.

These communications functions are provided through the use of space and ground-based antennas and network systems, mission control facilities, computational facilities, command management systems, data capture and telemetry processing systems, and a host of leased interconnecting systems ranging from phone lines and satellite links to optical fibers.

The program provides the necessary research and development to adapt emerging technologies to NASA communications needs. 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 study and coordination of data standards and communication frequencies to be used in the future. 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.

Many science and exploration goals require inter-agency or international cooperation in order to be achieved. NASA's Space Communications assets are provided through collaborative agreements to other U.S. Government agencies, commercial space enterprises, and international cooperative programs. Consistent with the National Space Policy, NASA will purchase commercially available goods and services to the fullest extent feasible, and will not conduct activities with commercial application that preclude or deter commercial space activities.

The Mission Communications Services program, one part of NASA's Space Communications program, provides services 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.

Efforts are ongoing to consolidate and streamline major support contract services in order to optimize space operations. In FY 1996, a voluntary contractor partnership was established between the major incumbents, AlliedSignal Technical Services Corporation and Computer Sciences Corporation. Transition to a Consolidated Space Operations Contract (CSOC) is planned. The CSOC acquisition process will be implemented in two phases. In FY 1997, multiple short-term fixed-price study contracts to develop an Integrated Operations Architecture (IOA) are planned. In FY 1998, a single cost-plus-award-fee, ten-year contract is envisioned to implement the IOA. A full and open competition is planned to develop an integrated architecture and implementation across all NASA programs to produce efficiencies and economies over the life of the contract.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### GROUND NETWORK

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Deep Space Network - Systems | 102,000 | 92,900 | 80,900 |
| Deep Space Network - Operations | 84,600 | 87,500 | 80,600 |
| Spaceflight Tracking and Data Network - Systems | 6,100 | 2,400 | 3,000 |
| Spaceflight Tracking and Data Network - Operations | 22,200 | 19,300 | 17,100 |
| Aeronautics, Balloons, and Sounding Rockets - Systems | 19,600 | 19,400 | 20,000 |
| Aeronautics, Balloons, and Sounding Rockets - Operations | 25,000 | 24,100 | 23,100 |
| Total | 259,500 | 245,600 | 224,700 |

### 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 STS is also provided by 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 Network 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).

The AlliedSignal Technical Services Corporation and the Computer Sciences Corporation are the primary support service contractors responsible for ongoing engineering and operations of the Ground Networks. For GSFC, the two contractors established a voluntary partnership in 1996 for engineering and operations support under the Consolidated Network and Mission Operations (CNMOS)performance-based contract.

The number of missions serviced by the DSN facilities and the needs 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 being phased out or converted for alternate uses. The DSN is being reconfigured with three 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 which are in critical phases. In Goldstone, two new 34-meter antennas became operational in FY 1995 and FY 1996. In Canberra, one will become operational in FY 1997. In Madrid, one will become operational in FY 1998. In addition, two experimental 34-meter antennas were obtained by NASA at Goldstone from the Army. The first of these former Army antennas became operational in early FY 1996 and is currently supporting the European Space Agency (ESA)-NASA collaborative Infrared Space Observatory and Solar Observatory for Heliospheric Observations spacecraft. Activities on the second Army antenna have been deferred due to constrained budget authority.

The DSN installed a new 11-meter antenna system at each DSN complex to provide data acquisition capability for the Institute of Space and Astronautical Science (ISAS) Japanese VLBI Space Operation Program (VSOP) spacecraft, which is scheduled for launch in February 1997.

Other new Ground Networks capabilities include 11-meter antenna systems at the University of Alaska, Fairbanks, and at the WFF Orbital Tracking Station for use with the Japanese/U.S. Advanced Earth Orbiting Satellite mission (ADEOS) and other NASA missions. Two additional 11-meter antenna systems are under contract by WFF to provide data acquisition capability for the expanded number of Earth-observing missions. One of these 11-meter antennas will be installed at Svalbard, Norway, and the other antenna will be installed near Fairbanks, Alaska.

When required, the Ground Networks program develops new capabilities to support unique requirements of NASA and NASA Cooperative Science missions, such as the Galileo S-band Mission Telemetry Array which utilizes a full-spectrum-recording technique and arrays the signals received simultaneously at antennas in Australia and California. The reference frequency transfer for VSOP and the world-wide coverage provided for ADEOS are other examples of enabling capabilities.

The strategy for achieving the above goals has five major elements:

- The DSN is the premier facility for tracking deep space probes. It is occasionally supplemented by the facilities of other agencies or nations. For example, the Australian Parkes radio telescope antenna is used to complement DSN coverage for the Galileo mission.

- The communications needs of present and future Earth resource observation missions can be partially or completely serviced by commercially available systems. NASA will obtain these systems from U.S. industry on a competitive basis.

- NASA is actively working with industry to foster the enhancement of existing "commercial-off-the-shelf' systems to expand their applicability, so that inexpensive and reliable telecommunications services can be readily obtained for the new small-class missions. Future missions will be supported by small, inexpensive, commercially available tracking systems.

- 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 will seek to minimize future tracking and navigation activities, resulting in lower operational costs. Two planned flights, Lewis and Student Nitric Oxide Explorer (SNOE), will demonstrate these new capabilities using commercial flight units as the primary source of this function.

- The WATR 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 STS and communications with the Mir Space Station. Intense planning is underway to support the **X-33** RLV Technology Flight Demonstrator with WATR resources.

The following cost reduction initiatives are underway:

- The cost of operating the DSN is being reduced through re-engineering efforts now in process. These new processes will allow the DSN to double the tracking hours delivered while reducing the cost of these processes substantially. The processes to be implemented include: moving toward giving the operators end-to-end control of the entire data acquisition process; redesigning systems that provide support data to allow automation and quicken response time: and developing a process to better define DSN services and allow customers to choose only the services necessary to support the mission.

- Efforts to reduce the cost of operations for low-Earth orbit spacecraft will continue with development of new technology and operational processes. The goal of these efforts is to provide turn-key mini-systems that can be operated directly by the flight projects. This concept will be validated by the Lewis Project and SNOE Project.

- Re-engineering efforts will continue on the STDN facilities to reduce operation and maintenance costs. NASA will close the Bermuda station, following completion of two planned STS modifications. One will permit earlier communications through the Tracking and Data Relay Satellite (TDRS) during the launch phase of the mission and the second will allow onboard use of the GPS to replace the use of ground radar for STS navigation. Closure **of** the Bermuda station is anticipated in FY **1999.**

- NASA will pursue, within the CSOC, commercial ground tracking services for low-Earth orbit missions that require this support. Transition activities to the commercial operator are expected to begin 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 commitments. The DSN will return to servicing only deep space missions, highly elliptical Earth orbiting missions, ground-based radio astronomy, and planetary radar astronomy activities.

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Current | plan |
| **Deep Space Network** | | | | | |
| Number of NASA missions | 46 | 46 | 45 | 45 | 45 |
| Number of hours of service | 73,000 | 73,000 | 93,000 | 90,000 | 92,000 |
| **Spaceflight Tracking and Data Network** | | | | | |
| Number of STS launches | 7 | 8 | 7 | 7 | 7 |
| Number of ELV launches | 10 | 26 | 6 | 18 | 6 |
| **Wallops Flight Facility** | | | | | |
| Number of NASA Earth-Orbiting missions | 30 | 30 | 30 | 33 | 33 |
| Number of Sounding Rocket deployments | 28 | 22 | 30 | 25 | 25 |
| Number of Balloon deployments | 22 | 25 | 22 | 26 | 26 |
| Number of hours of service (Wallops Orbital Tracking) | 31,000 | 26,720 | 31,000 | 23,000 | 26,000 |
| **Western Aeronautical Test Range** | | | | | |
| Number of NASA missions | 1790 | 967 | 2236 | 1,100 | 1,100 |
| Number of NASA research flights | 620 | 304 | 780 | 400 | 400 |

The FY 1997 and FY 1998 increase in DSN hours of service beyond the plan/actuals for FY 1996 was due to mission coverage for missions whose launches were delayed from previous years, such as Total Ozone Mapping Spectrometer (TOMS),Fast Auroral Snapshot Explorer (FAST),and International Solar Terrestrial Physics (ISTP)/Polar. In addition, the delay in decommissioning DSS-12 provided several months of available support which had not been anticipated. The increase in ELV support in FY 1996 and FY 1997 includes commercial and DOD launches. The changes to the Balloon and Sounding Rockets mission model plans were driven by customer readiness to launch. The reduced WFF orbital tracking in FY 1996 and FY 1997 is due to reduced mission requirements, particularly the International Ultraviolet Explorer (IUE) mission. The decrease in WATR support is attributed to early success in research programs which made some flights unnecessary and delays in completing aircraft modifications.

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the STS launches were successfully supported through dedicated facilities of the STDN. The two major requirements for the STDN are always, without exception, to be available during the launch countdown sequence so as not to cause a launch hold condition, and to provide at least 99% of the STS data during the launch phase. These requirements were met 100% of the time. The continuation of this support, further enabled by the implementation of the re-engineered STDN system elements, is expected throughout FY 1997 and FY 1998.

The Galileo spacecraft reached Jupiter and began its tour of the Galilean moons. Antennas at the DSN stations in Australia and the Parkes Radio Telescope will be arrayed with the 70-meter antenna in California to enable a greater return of Galileo science data over the next two years. In the area of educational outreach, NASA is working with the Apple Valley Science and Technology Center in California to encourage young people to become interested in Radio Astronomy and space communications. An obsolete 34-meter antenna at Goldstone, California is being reconfigured as a radio telescope to become an instrument for education.

WFF completed the installation of an 11-Meter Telemetry Antenna System at the University of Alaska's Synthetic Aperture Radar Facility. The system will primarily support the Japanese/U.S. Advanced Earth Observing Satellite Mission (ADEOS). WFF completed installation and testing of a Redstone Telemetry system at the White Sands Missile Range (WSMR). WFF also completed installation of a Redstone Telemetry System at Poker Flat Research Range. Both of these units will support sounding rocket launches. A 10-Meter Telemetry antenna, at the McMurdo Ground Station, became operational to support the Earth Resources Satellite (ERS) and RADARSAT missions. A contract was awarded to procure one Low Earth Orbit-Tracking (LEO-T) system with option to procure additional systems in the future.

The WATR supported over 1,000 aeronautics missions as well as all STS missions and Mir operations on a daily basis. Over 350 research flights were supported, many with extended duration (3 to 8 hours). In addition, combined system tests, full mission simulations, and data playbacks were conducted. Range safety and space positioning support for long duration, environmental research platforms and communications and tracking support for hosted programs (such as DarkStar) were provided. New challenges have been to post-flight process very high bandwidth data recorded onboard the Supersonic Laminar Flow Control research aircraft, and to develop an extended range capability for X-33 testing.

In FY 1997, the DSN will support two launches of the Mars Exploration Program. The Pathfinder Mission will land in July 1997, and Mars Global Surveyor (MGS) will begin orbital operations in September 1997. The Galileo Mission continues with the critical part of the tour, using the DSN array mode. Operational support for the ADEOS mission will continue. The VSOP spacecraft will launch in February 1997 and will begin a very complex operational scenario involving the 11-meter antennas for VSOP telemetry and the DSN 70-meter antennas for co-observing of the radio sources.

Low and sub-orbital flight mission services will be provided by permanent and transportable tracking facilities. These facilities will service low-Earth orbit, sounding rocket, and atmospheric balloon missions. WFF will install 11-meter systems in Svalbard, Norway and Fairbanks, Alaska, that will provide backup and housekeeping support to the Earth Observation System (EOS) AM-1 spacecraft and the Landsat-7 spacecraft. WFF will upgrade the MGS to provide command uplink and expanded S-Band downlink capabilities. FAST will be the first NASA mission to use these capabilities. The first LEO-T system will be installed and tested in Fairbanks, Alaska where it will initially support SNOE. A second LEO-T will be placed under contract for future installation at WFF. WFF will provide downrange ground station support, including telemetry, command, and radar, for the X-33 project at DFRC.

The Western Aeronautical Test Range will refurbish the DFRC radar systems; continue replacement of graphic displays in the mission control center; and overhaul DFRC telemetry antennas. The presentation of research data in real-time to researchers remote from DFRC is a key element to future success of the WATR and the research missions it supports. The "Virtual Flight

Research Center" and "Virtual Control Room" concepts will evolve based on work already done within the mission control community and the application of new network technology.

In FY 1998, both Cassini, bound for Saturn, and Lunar Prospector, a Discovery mission, will launch and be supported by the DSN. MGS will complete its orbital aerobraking and begin mapping the planet Mars. In July of 1998, the first of the Deep Space New Millennium missions will launch. About a month later, the Japanese Space Agency, ISAS, will launch Planet B. a Mars mission which will be supported by the DSN on a cooperative basis.

The capability to receive data from several spacecraft in a single beam will be implemented. This is required because of the number of missions that will be orbiting on the surface of Mars. This implementation will allow the DSN to better use the limited number of antennas that are available.

The aging DSN 34-meter standard antennas at Australia and Spain will be decommissioned. The support formerly provided by these antennas will be assumed by the newly constructed 34-meter antennas.

Re-engineering of the DSN network control system is ongoing and is scheduled for completion in FY 1999. Automated equipment will enable a single "connection operator" at a Complex to control the acquisition of data from a spacecraft and deliver it to a project.

The second LEO-T will be installed and tested at WFF. The modernization of the WFF FPQ-6 radar will be completed and verified. The automation of the Wallops Optical Tracking Station will be completed, tested and validated.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### MISSION CONTROL AND DATA SYSTEMS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Mission Control - Systems | 10,800 | 10,500 | 13,400 |
| Mission Control - Operations | 43,200 | 43,700 | 46,500 |
| Data Processing - Systems | 46,800 | 40,400 | 39,700 |
| Data Processing - Operations | 62,000 | 52,500 | 45,400 |
| Total | 162,800 | 147,100 | 145,000 |

## 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 GSFC spaceflight missions; data processing for NASA's Spacelab program; and flight dynamics requirements for NASA fight 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 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. In addition, the program advocates sustaining U.S. economic and technological leadership in commercial space communications and fostering the development of the National Information Infrastructure and the Global Information Infrastructure.

## 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 AlliedSignal Technical Services and Computer Sciences Corporation are the support service contractors responsible for ongoing engineering support, development, operations and maintenance, under the Consolidated Network and Mission Operations (CNMOS) performance based contract, established as a voluntary partnership in 1996.

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 interface with flight dynamics and communications network facilities in preparation of command sequences, perform the red-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.

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOC) for the Hubble Space Telescope (HST) program: the ISTP/Wind, ISTP/Polar, and Solar Observatory for Heliospheric Observation (SOHO); X-ray Timing Explorer (XTE), TOMS-Earth Probe (EP), Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) and FAST missions, and the Multi-satellite Operations Control Center (MSOCC) which supports the Compton Gamma Ray Observatory (CGRO), Upper Atmospheric Research Satellite (UARS), Extreme Ultraviolet Explorer (EUVE), Earth Radiation Budget Satellite (ERBS), and International Monitoring Platform (IMP) missions. Data processing support is provided for ISTP/Geomagnetic Tail (Geotail).

The EUVE and the CGRO system are phasing into a new Transportable Payload Operations Control Center (TPOCC) architecture of distributed workstations, first used for the SAMPEX 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. Tropical Rainfall Measuring Mission (TRMM), Advanced Composition Explorer (ACE), Transport and Atmospheric Chemistry near Equator (TRACE), and Wide Field Infrared Explorer (WIRE) control centers are in development. 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 November 1999. 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 data processing all into a single multi-mission control center. The control center system will be used for spacecraft integration and test, thereby eliminating the need and cost of spacecraft manufacturers integration and test systems.

GSFC is presently working with the University of California Berkeley (UCB) to install and test the TPOCC architecture in the EUVE Mission Operations Center. EUVE operations will be outsourced to UCB in mid-1997. Other mission control systems include the STS Payload Operations Control Center (POCC) Interface Facility (SPIF) and the Command Management System. The STS POCC Interface Facility was successfully transitioned to the TPOCC architecture in FY 1996. The SPIF provides a single interface to Mission Control Center for use of spacecraft mission control facilities to access spacecraft deployed by the STS. 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, is provided for scheduling communications with spacecraft supported by the Tracking and Data Relay Satellite System (TDRSS); the Flight-to-Ground Interface Engineering Center provides flight software pre-flight and in-flight simulation and development support for GSFC flight systems: and, 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 the following spacecraft missions: SAMPEX, EUVE, CGRO, SOHO, SWAS, XTE, TRMM, and HST.

The Data Distribution Facility performs electronic and physical media distribution of NASA space flight data to the science community. The Data Distribution Facility 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), and the Spacelab Data Processing Facility, located at the MSFC, processes data from STS payloads. Specialized telemetry processing systems for NASA's Space Network are 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 TDRS and the STS; 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; ease and low cost of operation: reuse of software: and selected use of advanced technology 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 and JPL. The GSFC team, including contractors and universities, provides advanced technology in several areas, such as tracking and data acquisition future systems; communications and telemetry transport; and advanced space systems for users. The JPL team advances technology in multiple areas such as spacecraft radio systems development and optical communications development; communications systems analysis: and flight demonstrations. The Mission Communication Services advanced technology development has two forms: near term (1-3years) demonstration and application of data management and telecommunications technology and procedures; and long-range (3-5years) development of ground and space flight communications systems.

Consideration of innovative applications of commercial "off-the-shelf" technology is emphasized. Such applications often open new market opportunities to suppliers of these technologies resulting from their NASA experience.

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. NASA continues to coordinate frequency spectrum requirements with other federal agencies, industry and regulatory bodies to obtain all requisite authorization 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 is the primary advocate, both domestically and internationally, 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 management policies.

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Current | plan |
| Number of NASA spacecraft supported by GSFC mission control facilities | 16 | 16 | 17 | 14 | 17 |
| Number of mission control hours of service | 50,000 | 49,000 | 52,000 | 50,000 | 55,000 |
| Number of billions of bits of data processed | 13,500 | 15,500 | 12,000 | 27,000 | 38,000 |
| Number of NASA missions provided flight dynamics services | 34 | 35 | 33 | 32 | 38 |

The current FY 1997 column reflects IUE termination, and ICE solar occultation. The FY 1998 plan reflects the SWAS, ACE, and TRMM launches. Increased bits of data processed reflects science instrument change out on the HST. FY 1998 plan reflects a planned launch for TRACE and transfer of EUVE to the University of California at Berkeley. The number of missions provided flight dynamics services reflects the current mission model and includes pre-Phase A and Phase A support for missions such as Earth Orbiter (EO)-1, Venus 2000, and Next Generation Space Telescope.

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the Mission Control and Data Processing program 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 CGRO and EUVE MOC operations to TPOCC workstation systems as a step to MSOCC closure and the installation of HST science processing to PACOR with attendant closure of the more costly HST Data Capture Facility.

Mission control was performed for the HST, CGRO, UARS, EUVE, IUE, SAMPEX, FAST, ICE, IMP-8, ERBS, TOMS-Meteor, TOMS-EP, XTE, ISTP/WIND, ISTP/POLAR, and ISTP/SOHO. In FY 1996, the XTE, ISTP/POLAR, ISTP/SOHO, TOMS-EP, and FAST spacecraft were deployed under the control of GSFC mission control facilities.

Packet data processing operations were provided for the HST, CGRO, EUVE, SAMPEX, FAST, SOHO, TOMS-EP, and XTE. The Time Division Multiplexed services were provided for the Geomagnetic Tail, UARS. ERBS, ICE, IMP-8, National Oceanic and Atmospheric Administration (NOAA)- **10,** POLAR, and WIND. Data processing for the Spacelab missions was performed at MSFC.

Orbit determination of the TDRS itself was provided, and 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 STS, Expendable Launch Vehicles, and satellite systems. A new operations concept for flight dynamics was developed. The new concept defines an approach to reduce flight dynamics costs by implementing new technology.

Among systems implementation projects in FY 1996, development of TPOCC systems for the upcoming TRMM and ACE spacecraft continued, including the procurement of workstations, processors, and software. TOMS-EP has been integrated into the **TOMS** mission control center. Modifications of the Command Management System effecting workstation deployment to specific MOC's progressed, with CGRO the only residual mission operating on a reduced configuration IBM mainframe. TPOCC development for the CGRO and EUVE missions continued in order to allow closure of the aging MSOCC facility by FY 1998. Preparations for the Second Servicing Mission for the HST continue with ground system software changes being made to accommodate the planned new space systems. FY 1996 marked the initiation of innovative spacecraft integration and test and mission operation single system ground support development efforts for both the MIDEX Microwave Anisropic Probe ***(MAP)*** and Smal-class Explorer (SMEX) TRACE and WIRE MOC's.

The spacecraft managed by GSFC's mission control facilities are supported by various NASA communications networks, including the TDRSS, the DSN, the WFF, and transportable ground systems. A wide range of communications and systems interfaces must be managed to accomplish the function of mission control. NASA mission operations personnel support the planning and development of future mission systems and continuous changes to operational spacecraft software systems, as well as the operation of current ground control systems.

Transfer of data systems technologies to flight project use occurred in the areas of software reuse, Very Large Scale Integration (VLSI) applications, expert system monitoring of spacecraft control functions, and packet data processing systems. Software reuse, expert systems, VLSI user interface, workstation environments, and object-oriented language applications continued. The Mission Control and Data Systems programs will continue to integrate modem technology into mission operations support systems through the use of systems like the Generic Spacecraft Analyst Assistant for automation, software-based telemetry front-end processing systems and the Mission Operations Planning and Scheduling System, and is exploring the use of case based reasoning tools.

In support of Advanced Technology Development, planning and implementation continued on demonstrating optical laser communications between the ground and an Earth-orbiting spacecraft using the JPL ground facilities and the Japanese ETS-VI satellite. A contract was placed for a 4th-generation, lightweight, low-power-consuming radio transponder for users of the **TDRSS.**

NASA continues to exercise its responsibilities for space communications in a cooperative manner with our international partners. We continued strategic planning panels with ESA and the National Space Development Agency (Japan) and instituted new relationships with the French Centre National d'Etudes Spatiales and German Aerospace Research Establishment organizations. We also established the groundwork for similar panels with the Russian Space Agency.

Consistent with the National Space Policy calling for the use of private sector communications systems by the government, initial steps were taken to identify technologies as well as systems and programmatic issues relative to the use of commercial assets.

In FY 1996, a detailed sharing assessment was conducted at the request of the White House Office of Science and Technology Policy to examine the feasibility of sharing between NASA Space Science systems and Local Multipoint Distribution Service (LMDS) systems near 27.5 GHz. The analysis, which showed the potential for harmful interference to space science systems, resulted in a decision by the Federal Communications Commission not to allocate spectrum below 27.5 GHz for LMDS.

In FY 1997, conversion of CGRO and EUVE to TPOCC systems will be completed, permitting the closure of the MSOCC facility. Attitude software and simulator development is being provided for the TRACE, WIRE, ACE, and TRMM flight systems. Transitioning the FDF to a workstation environment will be completed in FY 1997. The ACE, SWAS, and TRMM missions will be supported by GSFC's data processing program in FY 1997.

Reimbursable support will be provided to seven missions, including GOES and NOAA programs. Support will begin for ACE and TRMM missions in FY 1997. Mission planning for future missions such as TRACE, WIRE, FUSE, Landsat-7, and EOS will be performed.

Advanced technology will continue. The 4th generation TDRSS radio transponder engineering unit is underway. Work on deep space radio transponders and data coding technology continues.

FY 1997 will be a transitional year for many aspects of the Mission Control and Data Systems program. Mission Control and Data Systems will provide Mission Control Flight Dynamics and Data Processing service for the SWAS, TRMM and ACE missions scheduled to be launched in FY 1997. The SAMPEX mission will continue migrating operations to the University of Maryland at Bowie State, and transition of EUVE mission operations responsibilities to the University of California, Berkeley will be completed. Support to ICE will terminate. Significant development, test, and pre-launch support associated with MIDEX, and the SMEX missions, are part of the Mission Control and Data Systems activity.

The ACE and TRMM mission control centers (MCC) will be completed in FY 1997 and the ACE mission will be added to the data processing operational workload, Emphasis upon commercial products, artificial intelligence applications and advanced graphical

displays will be accelerated in FY 1997 for application in MIDEX and future SMEX missions. NASA's Command Management System is evolving to workstation-based systems integrated within spacecraft MCC capabilities.

In FY 1997, the HST Second Servicing Mission will be conducted from the HST control center; and transition to support of the next series of SMEX missions will begin. Development efforts will take place in preparation for TRACE, WIRE, and MIDEX missions. Efforts will continue for the FY 1997 HST Servicing Mission.

In FY 1997, the Mission Operations and Data Systems program will focus efforts at re-engineering selected ISTP/Wind, Polar, SOHO, and IMP ground elements to achieve dramatic reductions in recurring operations costs, enabling continued science operations beyond current termination dates. To promote operations automation in FY 1997, Mission Control and Data Systems will intensify development efforts on the XTE and EUVE Automated POCC (APOCC) and the CGRO Reduced Operations by Optimizing Tasks and Technologies effort. Automation will be provided for TRACE to promote single shift staffing for operations. Mission Control and Data Systems will actively lead and participate in establishing Renaissance directions and rapid prototyping, exploring system autonomy concepts, and use of commercial-off-the-shelf products.

Mission Control and Data Systems program will continue the lead in scoping and prototyping Mission Operations Control Architecture (MOCA) elements 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 participation in the American Institute of Aeronautics and Astronautics Spacecraft Control Working Group to infuse emerging operations standards in the areas of satellite control. Exploration of the promise of advanced communications technologies will continue throughout this period.

In N 1998, TRACE development will be completed, the MSOCC system will be closed, and the EUVE control center support will be completely transitioned to the University of California at Berkeley. Developments will continue for the MIDEX and SMEX series as well as for the Earth Orbiter (EO)-1 mission. Development efforts on WIRE, MAP, Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), EO-1, and similar missions will realize benefits from modem 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; etc.).

A new Flight Dynamics Facility (FDF) operations concept to perform routine operations as integral functions within mission control centers will be fully implemented in FY 1998. Portable (capability to operate anywhere) FDF support systems will be developed to facilitate distributed operations. The systems will offer options for customer operations, integrated operations and central operations. New technology development for autonomous space and/or ground spacecraft navigation and control will be major efforts.

In FY 1997, the space communications NASA/Industry/Academia alliance will be established. *An* industry workshop will be conducted by May 1997 to define technologies for NASA mission use. Studies will be initiated and databases created to explore the ability of emerging commercial assets to satisfy a portion of the Agency's communications needs. In N 1997 and continuing

through FY 1999, the alliance will become the primary vehicle for collaboratively developing pre-competitive technologies and conducting service enabling demonstrations of mutual benefit to the industry and **NASA.**

**NASA** and DoD continue to conduct joint technology projects in three key areas: more efficient use of the radio frequency spectrum: standardization of link and upper-level communications protocols for greater interoperability: and, miniaturization of global positioning satellite receivers for small satellite utilization. Efficient modulation techniques, with better than a 10-to-1 reduction in bandwidth requirement over present modulation techniques, will continue to be analyzed with follow up implementation of the most promising theoretical concepts. The seamless interface of space links with ground network fiber-optic stems will be analyzed and demonstrated by continuing the Space Communications Protocol Standards (SCPS) project. In addition, the evolution of link protocols to allow greater flexibility and demonstrations of upper level protocols to achieve improved interoperability and seamless communications between ground and space networks, will be initiated using the Mission Operations Control Architecture test bed. The use of onboard GPS receivers for navigation of small spacecrafts will require additional technology in miniaturization of current GPS receivers. **NASA** and DoD will continue to conduct joint design and evaluation projects for this purpose.

Work will continue on identifying future World Radiocommunications Conference (WRC) topics including advocating spectrum for space-to-space use of the Global Positioning Satellite network. The Spectrum program will support and advocate **NASA's** interest in WRC-97 and WRC-99.

## SPACE NETWORK CUSTOMER SERVICES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Space Network Customer Services ..... | 27,200 | 25,900 | 31,100 |

### PROGRAM GOALS

The Space Network Customer Service program goal 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 of 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 AlliedSignal Technical Services Corporation and the Computer Sciences Corporation are the primary support service contractors responsible for systems engineering, software development and maintenance. operations, and analytical services. The two contractors established a voluntary partnership in 1996 for these services under the CNMOS performance based contract.

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 systems. These will explore interoperability of the NASA Space Network and the National Space Development Agency (Japan)(NASDA)/ESA communications systems for mutual provision of emergency operational spacecraft support.

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Current | Plan |
| Number of NASA spacecraft events supported by the NCC | 60,800 | 60,800 | 59,400 | 61,000 | 74,400 |

The FY 1996 and FY 1997 number of NASA Spacecraft events supported by the NCC will remain fairly stable until the FY 1998 additions for support of Landsat-7, EOS AM-1, and Space Station assembly activities.

## ACCOMPLISHMENTS AND PLANS

In FY 1996, implementation was continued on an improved, distributed architecture for the NCC. When completed, this modification will provide more efficient use of the network capabilities, improved ability to resolve scheduling conflicts among customer missions, and provide standard commercial protocols for both internal and customer interfaces. This architectural change will be undertaken over several years and accomplished segment by segment. The segment of the control center to be modified first is the service scheduling system.

Studies have been conducted on the establishment of a more robust remote terminal capable of full service provision to users in the TDRS zone of exclusion. The implementation of a full service remote terminal on Guam began with the approved FY 1995 Operating Plan reprogramming action late in FY 1996. This terminal will eventually replace the current, less capable terminal located in Australia. This remote terminal has already proven invaluable in boosting the scientific return from the Compton Gamma Ray Observatory.

In FY 1997, NCC modifications to the scheduling system will continue including incorporation of standard commercial protocols into the control center interfaces. The development of a compact transponder, using new technology, suitable for use by new, small satellites will be continued. This dual award procurement will provide engineering models and a small number of flight units from both Cincinnati Electronics and Motorola. These small satellite transponders expand Space Network/TDRS use to a new class of missions. Antenna systems technology development for the smaller satellite class spacecraft will be initiated.

In FY 1998, the Space Network Customer Services program will provide for continued operations, maintenance, and modification of the NCC. The scheduling system modification will be completed and become operational. The communication and control segment modification effort will be initiated. This segment modification will complete the distributed architecture modifications and lower the life cycle cost of the Network Control Center.

The requested funding also provides for continuation of mission planning, customer requirements definition and documentation, mission and network operational analyses, customer communications systems analyses, test coordination and conduct, and other customer support services. An interoperability demonstration with the TRMM spacecraft and a Japanese data relay satellite precursor, Communications and Broadcasting Engineering Test Satellite (COMETS), will be conducted. Compatibility testing will be planned for TRMM, Landsat-7, EOS PM-1, International Space Station, WIRE, and upcoming NOAA missions in FY 1998.

Simulations, engineering tests and data flows will be conducted to verify communications designs and train mission control operators.

**Academic Programs**

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Education | 61,500 | 65,600 | 55,500 | SAT 6.1-1 |
| Minority research and education | 48,400 | 54,800 | 40,900 | SAT 6.2-1 |
| Total | 109,900 | 120,400 | 96,400 | |

Education
Programs

SCIENCE AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

## BUDGET SUMMARY

**ACADEMIC PROGRAMS** **EDUCATION PROGRAMS**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | Thousands of Dollars) | | |
| Student support programs | 10400 | 10000 | 9.400 | SAT 6.1-5 |
| Teacher/faculty preparation and enhancement programs | 14,800 | 14000 | 13400 | SAT 6.1-8 |
| Support for systemichange | 26.400 | 24.800 | 24.100 | SAT6.1-12 |
| Educational technology | 9.200 | 16.100 | 7.900 | SAT 6.1-16 |
| Evaluation | 700 | 700 | 700 | SAT6.1-19 |
| Total | 61.500 | 65.600 | 55.500 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | 1.100 | 1.300 | 1.300 | |
| Kennedy Space Center | 400 | 500 | 500 | |
| Marshall Space Flight Center | 2. 100 | 3.300 | 3.400 | |
| Stennis Space Center | 1.200 | 1.200 | 1.200 | |
| Ames Research Center | 3.600 | 3.000 | 3.100 | |
| Langley Research Center. | 1 ,000 | 1.100 | 1,200 | |
| Lewis Research Center | 900 | 1.900 | 1.000 | |
| Dryden Flight Research Center | 200 | 200 | 300 | |
| Goddard Space Flight Center | 3.900 | 42.200 | 32.500 | |
| Jet Propulsion Laboratory | 800 | 900 | 1.000 | |
| Headquarters | 46.300 | 10.000 | 10.000 | |
| Total | 61,500 | 65.600 | 55.500 | |

**ACADEMIC PROGRAMS** **EDUCATION PROGRAMS**

## PROGRAM GOALS

NASA's vision for education is set forth in the NASA Strategic Plan as one of the four strategic outcomes for the Agency:

> ***To promote the pursuit of educational excellence by involving 'the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds."***

This outcome is accomplished through implementation of a full range of NASA education programs which 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.

## STRATEGY FOR ACHIEVING GOALS

In carrying out its education programs, 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 and teachers, and channel this into education endeavors which support the National Education Goals, specifically to make American students first in the world in science and mathematics achievements.

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 teachers and students to experience first hand involvement with NASA's scientists and engineers, its facilities, and research and development activities. The participants benefit from the opportunity to participate in research and development endeavors, gain an understanding of the breadth of NASA's activities, and return to the classroom with excitement to share with the entire education community. NASA contributes to promoting excellence in education by sharing access and involvement in the NASA mission. Underpinning the entire Education Program is the commitment to involve participants from diverse and underrepresented populations in the science, mathematics and technology pipeline.

NASA remains an involved member of the National Science and Technology Council (NSTC)/Committee on Education and Training (CET). NASA's education activities are fully supportive of the NSTC Education Strategic Plans and the National Education Goals, three of which relate to mathematics and science education.

## NASA's Strategic Plan for Education

In 1993. NASA issued its first education strategic plan, NASA's Strategic Plan for Education: A Strategy for Change: 1993-1998. This roadmap set forth a comprehensive process to redirect and change the focus of the NASA Education Program. The key goals for NASA's Education Program are:

- To maintain that segment of NASA's current education program -- hereinafter referred to as the base or core program -- that is judged to be effective, based on internal and external customer measures of success. Such maintenance involves individual program revision, expansion, or elimination.

- To implement new education reform initiatives which specifically address NASA mission requirements, national education reform, and NSTC priorities.

- To significantly expand the impact of the NASA education program by developing partnerships with external constituencies.

- To articulate, develop, and implement a NASA education program and evaluation framework.

These goals are supported by enabling activities and management priorities to guide the change process. Since its publication, all NASA field centers and many enterprises have developed center/enterprise-specific strategic plans that are aligned with and support the Agency plan for education.

In 1994, NASA commissioned the National Research Council (NRC) to prepare a comprehensive set of recommendations for the organization and definition of these goals and enabling systems in accord with the management priorities that had been articulated. The NRC report, NASA's Education Programs: Defining Goals and Assessing Outcomes recommended a set of categories for integrating NASA's education goals with the mission of the agency and established the foundation for a solid evaluation program. Working with the NRC recommendations and the principles set forth in the NASA Education Strategic Plan, an agency framework for education programs and evaluation was established in 1994.

This framework integrates NASA's education programs, which touch the entire range of the education "customer" community, with the programmatic activities of NASA's Enterprises. Each category identifies a goal which reflects its role in relationship to the NASA mission, and is supported by performance measures for evaluation. These categories are:

- Student Support
- Teacher/Faculty Preparation and Enhancement
- Comprehensive/ Systemic Change
- Cumculum Support and Dissemination
- Educational Technology

Evaluation is an integral element of all five categories. The measures to be used to evaluate the performance of NASA's Education Program are based on the goals set out in the NASA Education Framework. Data is being collected to ascertain the levels of actual accomplishment based on the measured outcomes, using data collected from program participants during the programs, from follow-up studies, and from selected in-depth studies. NASA's evaluation system includes measures that:

1) Collect and analyze a full range of statistics describing the target population captured.

2) Collect and analyze a full range of program performance indicators which include program characteristics, content, processes, and practices.

3) Collect and analyze end-of-program and follow-up participant evaluation of programs, covering content: teaching techniques and tools: program value, presentations, processes, and materials: and recommendations and suggestions.

4) Collect and analyze a full range of statistics describing supplementary materials, type and distribution.

5) Collect and analyze participant description of products and services covering content, value, presentation, processes, use, and recommendations and suggestions.

6) Collect and analyze a full range of service performance indicators which include service characteristics, content, processes, and use.

*An* evaluation program of *this* scope and complexity cannot be implemented in a single stage. The program starts with NASA-wide programs coordinated from Headquarters and will include center-unique and enterprise-unique programs on an incremental basis, providing for a constant cycle of input, output, evaluation and change aimed at continuous improvement over the entire experience base. A beta test of standard data collection systems and instruments for Agency-wide education programs as well as selected program and center-unique data was conducted in FY 1996. Based on a review of this test, the data gathering instruments will be implemented on agencywide programs in FY 1997: other programs will be brought into the system on a continuing basis.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### N1 SUPPORT PROGRAMS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Elementary and secondary | 2,900 | 2,800 | 2,600 |
| Higher education | 7,500 | 7,200 | 6,800 |
| Total | 10,400 | 10,000 | 9,400 |

### PROGRAM GOALS

The goals of the Student Support Programs are: to use the NASA mission, facilities, human resources, and programs to provide information, experiences, and research opportunities for K-12, and undergraduate and graduate students to support the enhancement of knowledge and skills in the areas of science, mathematics, engineering, and technology.

### STRATEGY FOR ACHIEVING GOALS

#### Elementary and Secondary

At the elementary and secondary level, student support activities provide (a)programs which utilize the NASA mission, facilities, and resources; (b) experiences and information that are designed to promote student interest in mathematics, science, engineering and technology: and (c)exposure to research and/or research experiences to promote mathematics, science, engineering and technology awareness. Activities such as the Space Science Student Involvement Program (SSIP)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.

#### Higher Education

At the higher education level, student support activities provide undergraduate students exposure to and involvement in research activities; provide experiences that facilitate transition from undergraduate work to graduate studies in NASA-related areas; support students to pursue graduate studies in NASA-related areas; and facilitate continuing professional development and contributions to research in NASA-related disciplines. 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,

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Revised | plan |
| **Elementary and secondary** | | | | | |
| **Space Science Student Involvement Program** | | | | | |
| -- Entries/proposals(student participants) | 9,000 | 8,100 | 9,000 | 8,100 | 7,600 |
| -- Teacher participants | 1,200 | 1,600 | 1,000 | 1,600 | 1,500 |
| -- Schools | N/A | 778 | N/A | 778 | 725 |
| -- National awards | 14 | 26 | 14 | 26 | 26 |
| **SHARP/SHARP-PLUS** | | | | | |
| -- Student participants | 500 | 450 | 500 | 450 | 425 |
| **SAREX** | | | | | |
| -- Student participants | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| **Higher education** | | | | | |
| **Graduate Student Researchers Program** | | | | | |
| -- Student participants | 510 | 404 | 436 | 400 | 375 |
| -- Universities | 117 | 108 | 110 | 100 | 95 |

Currently, program activities in the above categories have a variety of evaluation mechanisms. In FY 1997, a high priority activity will be to further develop and implement key indicators as standards by which all program activities will be measured. These could include such outcomes as change in student interest, career aspirations/awareness, educational aspirations; participation in research activities; persistence to undergraduate or graduate degree: career path; career productivity; participation in other NASA programs and increased participation of underrepresented groups. NASA's education evaluation system (EDCATS)will become fully operational, providing for the collection, analysis, evaluation, and reporting of student support program data and program outcomes throughout the NASA system.

## ACCOMPLISHMENTS AND PLANS

### Elementary and Secondary

The student support programs implemented to provide experiences and exposure to NASA's mission are: SHARP/SHARP-PLUS, SSIP and SAREX. These are a series of programs that capture interest in mathematics, science, engineering, and technology, and channel that interest into mathematics, science, engineering, and technology career paths.

In FY 1996. the SHARP/SHARP-PLUS program involved more than 450 underrepresented minority high school students in intensive research apprenticeships with NASA and active 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 enhance science, mathematics, engineering, and technology interests and capabilities of students in groups traditionally underrepresented in these fields. In FY 1997, enrichment opportunities will be explored, such as greater involvement in community service projects. In FY 1998, the program will continue, but with fewer student participants due to a projected reduction in the overall budget for student programs.

The Space Science Student Involvement Program (SSIP) is another very effective program managed in collaboration with the National Science Teachers Association, National Council of Teachers of Mathematics, and the International Technology Education Association, that promotes literacy in science, mathematics, and technology among U.S. students in grades 3-12. In FY 1996, more than 1,500 teachers and 8,000 students participated in and entered contests that demonstrated the students' skills in science as well as art, graphics, and writing. By FY 1997, the program will include fourteen competition activities, encompassing all 50 states, Puerto Rico and the District of Columbia through eight geographical regions. In addition, the program will be redesigned to insure closer linkages with the NASA enterprises. In FY 1998, the program will continue in its redesigned state, but with fewer student and teacher participants due to a projected reduction in the overall budget for student programs.

The Shuttle Amateur Radio Experiment (SAREX) provides students the opportunity to participate directly in the Shuttle program through the use of technology. Through actual communication with Shuttle astronauts via amateur radio, and supporting activities, students gain first-hand knowledge of the Shuttle program and its science objectives. SAREX is a mid-deck payload on the Shuttle, and is manifested on 3-5 flights per year, with 3- 10 school contacts per flight. This program is accomplished in collaboration with the American Radio Relay League's extensive volunteer network and during FY 1996, involved more than 10,000 students per mission, worldwide. The program is expected to include approximately the same number of students in FY 1997 and FY 1998.

## Higher Education

At the higher education level, the GSRP, initiated in 1980, provides graduate fellowships nationwide to post-baccalaureate U.S. citizens to conduct thesis research. Awards are made to a graduate student for a maximum of three years. On an annual basis, NASA supports approximately 400 graduate students pursuing masters or doctorate degrees in areas compatible with NASA's programs in Earth/space science, aeronautics, and aerospace technology. The request in FY 1997 will maintain the fellowships close to the current Ievel. In addition, linkages will be explored with programs at the precollege level, such as SHARP/SHARP-PLUS, in an effort to broaden the participation of all students in mathematics, science, engineering, and technology fields. The program will continue in FY 1998 but with fewer students supported due to a projected reduction in the overall budget for student programs.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### TEACHER/FACULTY PREPARATION AND ENHANCEMENT PROGRAMS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Elementary and secondary | 5.200 | 5,000 | 4,700 |
| Higher education | 9.600 | 9,000 | 8.700 |
| Total | 14,800 | 14,000 | 13,400 |

## 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 teachers and faculty to support the enhancement of knowledge and skills, and to provide access to NASA information in science, mathematics, technology, and engineering.

## STRATEGY FOR ACHIEVING GOALS

### Elementary and Secondary

At the elementary and secondary level, preparation and enhancement activities are designed to utilize the NASA strategic enterprises and the process by which new knowledge is discovered to demonstrate the application of mathematics, science and technology in student learning; enhance teachers' capability to design lessons and experiences that use scientific inquiry to affect student learning: encourage a "multiplier" effect to extend the benefits of the in-service program beyond participants to other teachers and students; and provide access to and promote utilization of NASA related materials and information resources. Pre-service programs such as Project NOVA, and in-service programs such as NASA Education Workshops for Elementary School Teachers (NEWEST). NASA Education Workshops for Math, Science, and Technology Teachers (NEWMAST), and 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.

### Higher Education

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 underrepresented groups, underfunded institutions): and provide opportunities for curriculum expansion/revision that aligns with the mission needs of NASA and universities. At the higher education level,

activities such as the Summer Faculty Fellowship Program (SFFP)and the NASA/University Joint Venture (JOVE) Program 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.

**MEASURES OF PERFORMANCE**

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | Plan | Revised | plan |
| **Elementary and secondary** | | | | | |
| **Project NOVA** | | | | | |
| -- University teams | N/A | 33 | N/A | 33 | 30 |
| -- Teacher participants | N/A | 100 | N/A | 100 | 95 |
| **NEWEST/NEWMAST** | | | | | |
| -- Teacher participants | 265 | 225 | 250 | 225 | 210 |
| **STEP** | | | | | |
| -- Teacher participants | N/A | 300 | N/A | 300 | 285 |
| **UCEP** | | | | | |
| -- Teacher participants | 770 | 958 | 800 | 1.243 | 1.140 |
| -- Schools | N/A | 82 | N/A | 103 | 95 |
| **Teaching from Space** | | | | | |
| -- Educational videotapes with resource guides | N/A | 3 | N/A | 3 | 3 |
| -- Educational videoconferences, reaching 20,000+ teachers | N/A | 4 | N/A | 4 | 4 |
| -- Other instructional products | N/A | 5 | N/A | 5 | 5 |
| **Higher education** | | | | | |
| **Summer Faculty Fellowship Program** | | | | | |
| -- Faculty participants | 314 | 314 | 300 | 275 | 260 |
| -- Colleges/universities | 196 | 195 | 180 | 170 | 160 |
| **JOVE** | | | | | |
| -- Faculty participants | 178 | 263 | 162 | 263 | 175 |
| -- Colleges/universities | 95 | 130 | 89 | 130 | 85 |
| **Innovative Research** | | | | | |
| -- Research grants | 22 | 30 | 22 | 30 | 28 |

Currently, program activities in the above categories have a variety of evaluation mechanisms. In FY 1997, these evaluation mechanisms will be incorporated into EDCATS including such outcomes as change in student interest, career aspirations/awareness, educational aspirations; participation in research activities: persistence to undergraduate or graduate degree; career path: career productivity; participation in other NASA programs: and increased participation of underrepresented groups.

## ACCOMPLISHMENTS AND PLANS

### Elementary and Secondary

By targeting educators as part of NASA's education strategy, programs such as Project NOVA, NEWEST/NEWMAST, STEP, UCEP, and Teaching from Space, play a significant role in ensuring that students and educators alike are provided today with the tools they will need tomorrow. Teacher preparation programs such as Project NOVA disseminate nationally an undergraduate pre-service model based on standards and benchmarks for science, mathematics, and technology. Teacher enhancement programs provide opportunities for in-service teachers to update their backgrounds and skills in science, mathematics, and technology. NEWEST/NEWMAST provides a leadership opportunity for 225 outstanding teachers; STEP provides actual center laboratory experience for 300 teachers: and UCEP provides more than 900 urban teachers greater exposure to new NASA knowledge. Using multiple formats, Teaching From Space develops products that are incorporated into enhancement activities, providing tools that can be applied in the classroom and disseminated through the Teacher Resource Center Network.

The impact of slightly reduced funding levels in FY 1997 will be evidenced by slightly lower participation rates in workshops or in a reduced number of workshop opportunities. Programs such as NEWEST/NEWMAST will develop an increased emphasis on technology. Other center-based teacher workshops will increase the amount of time spent in a laboratory setting. In an effort to reach a broader population, UCEP programs will be conducted in Tulsa, OK, Wichita, KS, the Territory of Guam, and southern Texas.

In FY 1998, projected budget reductions in teacher preparation and enhancement programs will result in reductions in the number of participants in most programs.

### Higher Education

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 300 university faculty are supported annually for ten weeks. Evaluations of the program, conducted by the American Society for Engineering Education (ASEE) indicate that approximately 30-40% of the participating faculty subsequently receive NASA research grants or contracts

The Joint Venture (JOVE)Program also provides opportunities for college and university faculty to come to NASA centers to work with NASA data and to enhance research and teaching capabilities. JOVE is managed by the Marshall Space Flight Center, where it was initiated as a pilot program in FY 1989. NASA provides scientific on-line data from space missions, as well as support for electronic work stations and partial faculty and student support. In turn, the universities agree to grant faculty release time, provide student support, and develop an instructional unit on a space science topic. There are currently 130 academic institutions participating, most of whom had little previous contact with the agency.

Since both SFFP and JOVE have similar objectives, i.e., to enhance the research and teaching capabilities of individual faculty members and their institutions, these programs will be reviewed in FY 1997. It is NASA's intent to take the best of both programs -- center research opportunities of SFFP and follow-on opportunities of JOVE -- and create a new program that would begin in FY 1998.

The Innovative Research Program is managed through the Offices of Space Science, Life and Microgravity Sciences and Applications, and Mission to Planet Earth, to support basic and applied research and analysis which is of a highly innovative nature. This program is intended to provide a mechanism for the funding of scientifically sound proposals which might not be funded through normal channels either because of their interdisciplinary nature or because they are speculative or risky. The long-gem goal is to help the new ideas mature to a state of acceptability within a particular science discipline. FY 1996 was the second year of a three year cycle, with 30 grants being funded (out of 612 proposals received). A new group of proposals will be funded in FY 1998, although at slightly reduced levels.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SUPPORT FOR SYSTEMIC CHANGE

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Aerospace Education Services Program (AESP) | 6,200 | 6,100 | 5,600 |
| National Space Grant College and Fellowship Program | 14,600 | 13,600 | 13,300 |
| Experimental Program to Stimulate Competitive Research | 4,900 | 4,500 | 4,600 |
| Innovative Reform Initiatives | 700 | 600 | 600 |
| Total | 26,400 | 24,800 | 24,100 |

## PROGRAM GOALS

The goal of the Support for Systemic Change Program is to support local, state, regional, and national efforts to enhance the goals of the educational community through individual or collaborative efforts with a range of partners.

Systemic change encompasses the process whereby an entire system is re-engineered toward achieving a new goal. As an example, a superintendent's agenda for change in the public schools might include: school based management: curricula changes to support state standards: increased teacher enhancement support: inclusion of technology access and use by all students: or creation of new student assessment systems. 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. 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

### Elementary and Secondary

Support for Systemic Change activities at the elementary and secondary level use NASA personnel and resources to contribute to K-12 mathematics, science, and technology education reform by promoting the involvement of various community sectors: and target a cross-section of schools and organizations which serve a variety of participants, including those from underrepresented groups. 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 the National Science Foundation's (NSF)and state/local systemic change initiatives.

### Higher Education

## Higher Education

Support for Systemic Change 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 movement.

The Space Grant Program was authorized by Congress in 1987 to increase the understanding, assessment, development, and use of space resources. All 50 states, Puerto Rico, and the District of Columbia have Space Grant Consortium programs in which more than 550 institutions participate. These consortia form a national network of colleges and universities with interests in aerospace research. training, and education. All consortia match their grants at 100% in either dollars and/or cost sharing arrangements (excluding the portion designated for fellowships) to carry out programs of education, public service, and research.

The FY 1993 NASA Authorization Act (P.L. 102-588) directed NASA to initiate a program to strengthen the research capability of states that do not successfully participate in competitive space and aeronautical research activities. The NASA EPSCoR Program, modeled after the National Science Foundation's EPSCoR, 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 change at both elementary and higher education levels is captured in NASA's Innovative Reform Initiatives program which is supportive of standards-based systemic reform efforts and NSTC/CET priorities, and focuses on science, mathematics and technology education. A means of accomplishing systemic reform 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).

**MEASURES OF ANCE**

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | Revised | plan |
| **AESP** | | | | | |
| -- Schools visited | 2,000 | 353 | 1,500 | 400 | 365 |
| -- Teacher workshops | 2,500 | 1,914 | 2,000 | 2,000 | 1,850 |
| -- Teacher participants | 19,000 | 20,369 | 18,500 | 21,000 | 19,300 |

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Revised | plan |
| **UCEP** | | | | | |
| -- Consortia | 52 | 52 | 52 | 52 | 52 |
| -- Institutions | 550 | 550 | 550 | 550 | 550 |
| **EPSCoR** | | | | | |
| -- Awards | 14 | 6 | 10 | 10 | 10 |
| -- Institutions | N/A | 42 | N/A | 55 | 55 |

Currently, program activities in the above categories have a variety of evaluation mechanisms. In FY 1997, a high priority activity will be to further develop and implement key indicators as standards by which all program activities will be measured. These could include such outcomes as the establishment of partnerships, increased resources, proposals submitted, proposals funded, papers in peer reviewed publications, presentations to professional societies, and new ways of conducting business. NASA's education evaluation system (EDCATS)will become fully operational, providing for the collection, analysis, evaluation, and reporting of comprehensive/support for systemic change program data and program outcomes throughout the NASA system

**ACCOMPLISHMENTS AND PLANS**

The Systemic Change programs address many different levels within the education community and include AESP, Space Grant, EPSCoR and Innovative Reform Initiatives.

The AESP has been redirected to an emphasis on teacher enhancement, so that specialists are now directly involved in supporting state systemic reform by providing technical linkages to NASA research and development and education programs and services. Funding in FY 1997 and FY 1998 will continue operation of this program, although projected reductions in FY 1998 will result in fewer teacher workshops conducted around the country.

In FY 1997, Space Grant plans will focus on creating effective linkages between components of the Space Grant and EPSCoR Programs, and the NASA Centers. The program will continue in FY 1998, but projected budget reductions will delay planned program enhancements such as increasing the current funding amount for existing consortia, and exploring additional outreach opportunities such as linkages with national extension programs.

FY 1996 marked the third year of the NASA EPSCoR program with continued funding for the original six awardees. These six consortia, in their first 2.5 years of operation, produced 225 refereed papers and were awarded $62M in successful proposals. The original six awardees were evaluated at the end of FY 1996 to determine their eligibility for an additional two-year award. Five states were evaluated by a panel of NASA officials to be worthy of two additional years of funding. One state will receive at least one additional year, with recommendations for improvement. In addition, 14 proposals were received for the second round of NASA EPSCoR awards, with four new states selected in late FY 1996: Kansas, Nebraska, Oklahoma, and South Carolina. This

brings the current number of NASA EPSCoR awardees to 10. Funding levels for FY 1997 and FY 1998 will maintain the current program with no new solicitations planned.

NASA's Innovative Reform Initiatives program supports standards-based systemic reform efforts and priorities, and focuses on science, mathematics and technology education. To prevent duplication and to strengthen the impact of systemic reform initiatives, NASA confers with other Federal agencies and national organizations who are also working with educational systemic reform, including the National Science Foundation, Education Department, National Research Council, National Science Teachers Association, National Council of Teachers of Mathematics, International Technology Education Association, Council of Chief State School Officers, and the Smithsonian Institution. 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), the Tri-State Education Initiative (TSEI), and the Aerospace Education Alliance. These partnerships are each mutually beneficial in creating systemic change by increasing the customer and support bases for both NASA and the partnering stakeholder.

NASA's Education Division held a workshop in late calendar year 1996, in partnership with NASSMC, entitled "Linking Leaders for Systemic Reform." This workshop brought together NASA principal investigators, education, science and mathematics coalition leaders from the states of Ohio, Mississippi, and Colorado to focus on systemic change in those states. The Division is also supporting a week-long training workshop for the Council of State Science Supervisors (CS3) at NASA's Classroom of the Future to enhance participants' understanding of NASA discoveries and to provide training in the effective utilization of technology in the learning process. This workshop was requested by CS3. Similar opportunities will be explored in FY 1997 and FY 1998.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### EDUCATIONAL TECHNOLOGY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Learning tools | 2,000 | 2,000 | 1,900 |
| Demonstrations | 2,000 | 2,000 | 1,800 |
| HPCC | 2,200 | 1,400 | 4,200 |
| South Dakota Discovery Center | 1,500 | -- | -- |
| Montana State University Teacher Resource Center | 1,000 | -- | -- |
| Network for Education and Research in Oregon (NERO) | 500 | -- | -- |
| National Prototype Space Education Curriculum | -- | 1,600 | -- |
| Museum Initiative/American Museum of Natural History | -- | 8,000 | -- |
| Upgrades to Mobile Aeronautics Education Lab | -- | 300 | -- |
| Feasibility Study, National Residential High School, LeRC | -- | 250 | -- |
| Replication of Science, Engineering, Mathematics and Engineering Academy (SEMMA) | -- | 250 | -- |
| Classroom of the Future, Astronomy Village | -- | 300 | -- |
| Total | 9,200 | 16,100 | 7,900 |

## PROGRAM GOALS

The goal of the Educational Technology program is to use the unique assets of NASA to provide products and services that facilitate the application of technology to enhance the educational process for formal education and lifelong learning.

## STRATEGY FOR ACHIEVING GOALS

The educational technology program addresses two primary areas: (1) Development of High-Quality, Affordable Learning Tools and Environments, and (2) Demonstrations of Innovative Technology and Networking Applications. These tools and demonstrations utilize NASA's mission and research results as the content for technology-based programs for educators and students. The educational technology program is also designed to support two of the Administration's four pillars for educational technology. The two pillars supported by our program are to (1) develop effective and engaging software and on-line learning resources as an integral part of the school curriculum, and (2) provide all teachers the training and support they need to help students learn through computers and the information superhighway. Specific learning tools being developed to support the first pillar include:

1) ***Astronomy Village.*** a multimedia program for 9-12 grade science;
2) *BioBLAST*, a multimedia/network program for high school biology:
3) ***Tools*** of ***Aeronautical research*** a high school physical science program:
4) ***Liftoff to*** Learning, a series of videotapes featuring onboard sequences videotaped on the Space Shuttle: and
5) ***Virtual*** Exploration of ***Mars***, a learning tool based on virtual reality technology.

NASA Spacelink, an interactive network system for educators, and the videoconference series, On the Cutting Edge, address the second pillar. Additionally, all learning tools are designed to include a teacher training component.

The NASA Classroom of the Future continues to be the 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 which support standards-based education reform.

The Center-based K-12 Internet Initiative, which is part of the HPCC program, provides demonstration projects and on-line systems dedicated to bringing real 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 facilitate the use and technologies of the infrastructure within the K-12 education systems. NASA, led by Ames Research Center, organizes various interactive on-line projects that connect classrooms with ongoing science and engineering work. The projects provide real and relevant content to enhance classroom curriculums. For example, Live from the Hubble Space Telescope provided students the opportunity to interact with scientists using the HST to make new astronomical discoveries.

## MEASURES OF PERFORMANCE

| | |
|---|---|
| **Teacher Resource Center Network** | 200,000 + users at 73 locations in 47 states |
| **NASA Spacelink** | 1,363,000 total sessions: 208,000 sessions averaging 20 minutes/session from 1,800 registered educator accounts |
| **HPCC/IITA** | 25 World Wide Web sites ("Quest", Passport to Knowledge - Live From..." series<br>2000 schools involved in K-12 aeronautics cooperative agreements |

## ACCOMPLISHMENTS AND PLANS

Educational Technology activities support the development of high quality, affordable learning tools and environments (e.g., CD-ROM databases. 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. For example, NASA Spacelink

recorded 1,363,000 total sessions with 208,000 sessions averaging 20 minutes/session from over 1,800 registered educator accounts and several affordable networking technology projects have been demonstrated. Classroom of the Future continues to be NASA's major educational technology program.

NASA's Educational Technology program includes the center-based components of the High Performance Computing and Communications/Information Infrastructure Technology and Applications (HPCC/IITA) program. 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 seven center-based projects have made extensive amounts of Earth, space, and aeronautics information available on the Internet. Several of our Internet sites have received a top score from one or more independent rating services. These sites include: "Quest -- K-12 Internet Initiative" and "Passport to Knowledge". Through this program, collaborations are maintained with and support provided to 2,600 schools across the country.

In FY 1997, the Educational Technology program will begin the development of a virtual education server, incorporating services such as Spacelink and the HPCC/IITA sites, as well as other education sites, in an effort to provide more user-friendly access to NASA Education information. The Teacher Resource Center Network will be completely redesigned to insure national access and to make greater use of emerging educational technologies. In FY 1998, plans will be developed to implement a grant program calling for proposals from the education community to develop new learning tools based on NASA's mission and results. Projected budget reductions in FY 1998 will reduce the level and number of new grants that could be funded.

Funding is included in FY 1996 to support three activities directed by Congress in the Conference Report accompanying H.R. 2099: Science/Discovery Center in South Dakota, Teacher Resource Center at Montana State University, and additional funding for the Network for Engineering and Research in Oregon (NERO). Funding is included in FY 1997 for the following activities directed by Congress in the Conference Report accompanying the FY 1997 VA-HUD-Independent Agencies Appropriation Act (P.L. 104-204): National Prototype Space Education Curriculum in conjunction with the Bishop Museum in Hawaii: further development of the American Museum of Natural History/national center for science, literacy, education and technology; Upgrades to Mobile Aeronautics Education Lab.: feasibility study to create a national residential high school at the Lewis Research Center; Replication of the Science, Engineering, Mathematics, and Aeronautics Academy (SEMMA) Program at Cuyahoga Community College: and increase learning effectiveness of the Classroom of the Future, by assessing and improving student scientific inquiry abilities using the Astronomy Village Program.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### EVALUATION

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Evaluation | 700 | 700 | 700 |

### PROGRAM GOALS

The goal of the evaluation program is: to provide documented evidence of the degree to which NASA's educational program, with its associated projects and activities, has accomplished its goals: and to develop 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. Although every NASA education program currently has an evaluation component, a set of standard, agencywide indicators, metrics, and evaluation instruments is being developed for agencywide use. The data will be collected on-line in a single database capable of providing correlation and report generation capability. External education evaluation experts have also been engaged to provide guidelines and criteria for the analysis of qualitative and quantitative data to facilitate an in-depth survey of various programs offering recommendations and suggestions about the instruments in development.

### MEASU OF NCE

NASA is currently developing and testing a comprehensive system to evaluate its education programs in order to demonstrate the accomplishment of achievable and measurable goals and objectives. Based on recommendations provided by a study of NASA Education Program by the National Research Council (NRC),NASA has established program goals, defined a comprehensive Education Framework which captures the elements of NASA's Education Program. This framework is detailed in NASA's ***Strategic Plan for Education,*** and supported by strategic plans developed by the Enterprises and NASA Field Installations. NASA will utilize 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. This system, the Education Computer-Aided Tracking System (EDCATS),is currently in the test phase, using data from a selected group of national programs. This system will provide overall data and some in-depth data for FY 1997.

## ACCOMPLISHMENTS AND PLANS

NASA's education evaluation system (EDCATS) will become fully operational in FY 1997, adding 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. Funding included in FY 1997 and FY 1998 will support the gradual expansion of the EDCATS data base to encompass all of NASA's Education programs.

Minority University
Research and
Education

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS — MINORITY UNIVERSITY RESEARCH AND EDUCATION PROGRAM

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | (Thousands of Dollars) | | | |
| Historically Black Colleges and Universities | 28,000 | 31,300 | 25,500 | SAT6.2-6 |
| University Research Center Awards | (4,100) | (2,100) | (400) | |
| Institutional Research Centers Awards | (3,300) | (3,300) | (3,300) | |
| Principal Investigator Awards | (6,900) | (7,900) | (5,700) | |
| Math, Science, and Education Awards | (13,700) | (13,500) | (16,100) | |
| Partnership Awards | (--) | (4,500) | (--) | |
| Other Minority Universities | 20,400 | 23,500 | 15,400 | SAT 6.2-15 |
| University Research Center Awards | (1,700) | (1,800) | (400) | |
| Institutional Research Centers Awards | (2,700) | (2,200) | (2,300) | |
| Principal Investigator Awards | (6,600) | (7,300) | (4,800) | |
| Math, Science, and Education Awards | (9,400) | (7,800) | (7,900) | |
| Partnership Awards | (--) | (4,400) | (--) | |
| To | 48,400 | 54,800 | 40,900 | |

SCIENCE. AERONAUTICS AND TECHNOLOGY

FY 1998 ESTIMATES

BUDGET SUMMARY

| Distribution of Program Amount bv Installation | FY 1996 | N 1997 | N 1998 |
|---|---|---|---|
| | | (Thousandsof Dollars) | |
| Johnson Space Center | 1.069 | 3.138 | 930 |
| Kennedy Space Center | 734 | 1,439 | 930 |
| Marshall Space Flight Center | 1.244 | 1.465 | 1,150 |
| Stennis Space Center | 267 | 1.514 | 900 |
| Ames Research Center | 647 | 4.241 | 3.300 |
| Langley Research Center | 1.991 | 2.524 | 1,680 |
| Lewis Research Center | 1.320 | 1.965 | 930 |
| Dryden Flight Research Center | 122 | 1.162 | 480 |
| Jet Propulsion Laboratory | 1.784 | 2.078 | 1.050 |
| Goddard Space Flight Center | 17.834 | 35.274 | 29.550 |
| Headquarters | 21.388 | -- | -- |
| Total | 48,400 | 54,800 | 40,900 |

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 1998 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS MINORITY UNIVERSITY RESEARCH AM

## PROGRAM GOALS

The Minority University Research and Education Programs (MUREP)focuses 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). NASA's outreach to HBCU's and OMUs in FY 1998will build upon the prior years' investments in HBCU and OMU 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, HBCU's and OMU'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 HBCU's and OMUs, the strategic goals that guide NASA's MUREP are: (1) To foster research and development activities at HBCU's and OMU's which contribute substantially to NASA's mission: (2)To create systemic and sustainable change at HBCU's and OMU's through partnerships and programs that enhance research and educational outcomes in NASA-related fields: (3) To prepare faculty and students at HBCU's and OMU's to successfully participate in the conventional, competitive research and education process: and (4) To increase the number of students served by HBCU's and OMUs 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 both HBCU's and OMU's. These strategies include: (1)Working closely with NASA's Strategic Enterprises, other government agencies, and interested parties to develop new research and education collaborations and partnerships to build infrastructure in NASA-related research areas: (2) Providing annual opportunities for HBCU's and OMU's to participate in competitive peer review and merit selection processes for research and education awards: (3) Encouraging and providing opportunities for faculty to conduct NASA research early in their careers; (4) Providing incentives for students to enter and remain in mathematics, science and technology disciplines: and (5) Developing and implementing evaluations to assess the effectiveness of the programs and to improve program delivery and results. A strategy used to expand HBCU and OMU involvement in competitive peer review processes and to ensure the relevance of research conducted by HBCU's and OMUs is to involve NASA Strategic Enterprises early in the development of announcements of

opportunity (AO) for research. Once Headquarters issues the AO, NASA Installations are involved in providing advice to prospective grantees, in conducting peer reviews of proposals, and in providing funding recommendations to the Office of Equal Opportunity Programs (OEOP) and representatives from the Strategic Enterprises. Once Headquarters makes selections, the research is returned to the nominating NASA Installation(s) or Jet Propulsion Laboratory (JPL) for grant award and technical management of the award. OEOP provides policy direction, some funding, and oversight of the research conducted at HBCU's and OMU's.

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. Selections for these awards are made mostly through the competitive peer review and merit selection processes. These awards include:

- University Research Center Awards:
- Institutional Research Awards:
- Individual Principal Investigator's Research Awards:
- Awards for Mathematics, Science, Engineering and Technology (MSET) Education Initiatives: and,
- Partnership Awards.

The Partnership Awards were established in FY 1997 in response to Congressional direction included in the Conference Report accompanying the FY 1997 VA-HUD-Independent Agencies Appropriation Law (P.L. 104-204) specifying that additional funds be used for "...education programs which expand opportunities and enhance diversity in the NASA sponsored research and education community...". Selections for the Partnership Awards will be divided equally between the HBCU and OMU Programs.
Efforts will continue to ensure that HBCU's and OMU's are knowledgeable of and responsive to the Agency's efforts to institute program performance reform, to set specific program goals, measure program performance against those goals, and report publicly on their progress. These efforts should continue to enable HBCU's and OMU's to institute more effective planning, budgeting, program evaluation and fiscal accountability for NASA awards and funding. These collaborative efforts should enhance the effectiveness of NASA's HBCU and OMU Programs, and improve program outcomes, service quality, and customer satisfaction. NASA Strategic Enterprises and Program Offices continue to contribute financially and technically to the success of the Minority University Research and Education Program. In FY 1996 and again in FY 1997, they have made available $20.8M to support competitively selected research awards at HBCU's ($12.8M) and OMU's ($8.0M). Additionally, more than 98 technical personnel from across the Agency were involved in on-site reviews, informational forums and in providing on-site research activities for faculty and students from HBCU's and OMU's at NASA Installations and JPL.

During FY 1998, NASA MUREP will continue to focus on its strategic goals and strategies to integrate mission-focused research, technology transfer, and education at HBCU's and OMU's. Increased emphasis will be placed on partnership awards that leverage NASA's total research investment in higher education institutions and aerospace industry. Plans for new awards within the other designated award categories are dependent upon the number of expiring awards. Consequently, it is forecasted that opportunities will be provided for new Individual Principal Investigator's Research Awards and Awards for MSET Education Initiatives. In FY 1998, program efficiencies in the math and science awards categories are expected to result in an increase in the number of

students served. The financial investment of $20.8M by NASA Strategic Enterprises and Program Offices is expected to remain constant and their involvement and accountability for the research conducted at HBCU's and OMU's is expected to significantly increase in FY 1998.

## MEASURES OF PERFORMANCE

Metrics for NASA Minority University Research and Education Programs are being continually improved. Evaluations of individual awards within competitive MUREP award categories and for unsolicited awards continue to be performed, as succinct metrics are being developed to measure program outcomes, that can be aggregated both across and within award categories for the HBCU and OMU Programs.

Since FY 1994, a key priority has been to move from collecting data on just individual grant awards, to establishing key outcomes and collecting relevant data on HBCU and OMU research and education activities to measure progress in achieving those outcomes. Data has been collected on the first competitively selected individual principal investigator award recipients, the first selected undergraduate student researcher award recipients, the 1995 graduate student researcher award recipients, and the 1994 and 1995 University Research Centers performance. Based on the experience gained from these instruments, a Uniform Outcomes Data collection process is being instituted in FY 1997 for all education and research awards. The objectives are to establish uniform metrics for all NASA MUREP awards and to provide compact instruments for uniform collection of data keyed to those metrics. These metrics will reduce the collection of data to the minimal amounts possible, emphasize outcomes over processes, and be applicable to any project. They will be aggregated both horizontally and longitudinally, and they will allow adjustable benchmarking standards to be applied. The data will be collected electronically using the Internet, and a single annual collection of data will be used to provide the information necessary for comparative assessments of HBCU and OMU projects, and annual MUREP performance reports, including those required by the White House Initiative Offices on HBCU's, Educational Excellence for Hispanic Americans, and Tribal Colleges and Universities. Two instruments have been devised, one for basic research awards and the other for education awards.

These metrics for research and education programs will clearly indicate the impact of NASA's MUREP on the scientific and technological base for NASA and the Nation, while the uniform outcomes approach to collecting data will minimize the reporting burden on award recipients.

**BASIS OF FY 1998 FUNDING REQUIREMENT**

**HISTORICALLY BLACK COLLEGES AND UNIVERSITIES**

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| University Research Centers | 4,100 | 2,100 | 400 |
| Institutional Research Awards | 3,300 | 3,300 | 3,300 |
| Principal Investigator Awards | 6,900 | 7,900 | 5,700 |
| Math Science and Education Awards | 13,700 | 13,500 | 16,100 |
| Partnership Awards | --- | 4.500 | --- |
| Total | 28,000 | 31,300 | 25,500 |

**PROGRAM GOALS**

NASA's HBCU program is the Agency's direct response to Executive Orders 12232, 12876, and 12928, which require all Federal Agencies to strengthen the capacity of HBCU's to provide quality education, and to participate in and benefit from federal programs. This program aims to expand the research capabilities of selected HBCU's with emphasis on building research infrastructure and providing exposure to the NASA peer review process in order to increase opportunities for HBCU faculty and students to participate in and benefit from NASA's research and education programs.

**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 upon *two* recent Executive Orders. Executive Order 12876, signed November 1, 1993, 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 Order 12928, signed February 16, 1994, directs Federal agencies to promote procurement with "...Historically Black Colleges and Minority Institutions." NASA employs a comprehensive strategy to accomplish the HBCU program goals. This approach is carried out through awards in five areas:

- University Research Center Awards;
- Institutional Research Awards;
- Individual Principal Investigator Awards;

- Mathematics and Science Awards: and,
- Partnership Awards.

The NASA **HBCU University Research Centers (URC) Awards** began in FY 1991 with the establishment of seven HBCU Research Centers by the Headquarters Office of Space Science and Applications: the Office of Aeronautics: the Office of Space Flight: and the Office of Equal Opportunity Programs. The program goals are to achieve a broad-based, competitive aerospace research capability among the Nation's HBCU'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 of HBCU's in mainstream research: and increase the production of students, who are US citizens and who have historically been underrepresented, with advanced degrees in NASA-related fields. Four additional HBCU Research Centers were added as a result of a second competition in FY 1996. The two groups of URC's are referred to as "Group 1" and 'Group 2," respectively. Funding for the HBCU research centers is primarily provided by the Strategic Enterprises.

**GROUP 1 HBCU Research Centers:**

| University | Research Focus | Lead NASA Installation |
|---|---|---|
| Clark Atlanta University | High Performance Polymers and Composites (HiPPAC) Center | Lewis Research Center |
| Fisk University | Center for Photonic Materials and Devices | Marshall Space Flight Center |
| Florida A&M University | Center for Nonlinear and Nonequilibrium Aeroscience | Langley Research Center |
| Hampton University | Center for Optical Physics | Langley Research Center |
| Howard University | Center for the Study of Terrestrial and Extraterrestrial Atmospheres | Goddard Space Flight Center |
| North Carolina A&T State University | Center for Aerospace Research | Langley Research Center |
| Tuskegee University | Center for Food and Environmental Systems for Human Exploration of Space | Johnson Space Center |

**GROUP 2 HBCU Research Centers:**

| University | Research Focus | Lead NASA Installation |
|---|---|---|
| Alabama A&M University | Center for Hydrology, Soil Climatology and Remote Sensing | Marshall Space Flight Center |
| Morehouse School of Medicine | Space Medicine and Life Sciences Research Center | Johnson Space Center |
| Prairie View A&M University | Center for Applied Radiation Research | Johnson Space Center |
| Tennessee State University | Center for Automated Space Science | Goddard Space Flight Center |

In FY 1996, the Group 1 HBCU research centers were invited to propose for a second 5-years of funding at reduced levels. This opportunity to continue was offered in recognition of the experience gained from similar efforts at the National Science Foundation which showed that a 10-year period is necessary for new research centers to establish a base firm enough to become self-sustaining. It also allowed an opportunity to subject the Group 1 URC's to a substantial evaluation process by review teams of NASA technical managers and external university experts, who had not previously been directly involved in the URC Program. As a result, all of these HBCU research centers were deemed eligible to continue being funded for a second 5 years.

In order to foster closer ties between the HBCU research centers and NASA, a Lead NASA Installation has been designated for each URC. Beginning with the FY 1997 renewals, the Lead Installations will become responsible for directly managing the URC's cooperative agreements, and for increasing the HBCU's involvement in ongoing NASA research and development activities. Collaborations with other NASA Installations, industry, and other universities will continue to be strongly encouraged. The HBCU Research Centers, along with the OMU research centers, have formed the National Alliance of NASA University Research Centers (NANURC). This Alliance has established an annual National Conference of the University Research Centers, created pathways for developing greater collaborations between the University Research Centers, and is exploring avenues for increasing the number of advanced degrees being awarded to underrepresented minority students. NASA is strongly supportive of this concept and is actively working with the Alliance to further develop and strengthen their organization.

The goal of the **HBCU Institutional Research Awards** (IRA) is to improve academic, scientific and technology infrastructure and broaden the NASA-related science and technology base at HBCU'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. The second IRA (Network Resources and Training Sites [NRTS]) were open to HBCU's. The IRA (NRTS) award is designed to improve the in-house capability of HBCU's 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 HBCU'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) designating a lead HBCU as an NRTS: and (2) holding the lead HBCU accountable for providing internet connectivity to other HBCU's and/or OMU's and public schools, and for training students, faculty and teachers to build computers, maintain and effectively utilize the internet to compliment teaching and research collaborations and delivery. The lead NASA Installation, Goddard Space Flight Center (GSFC), manages the IRA (NRTS) under the auspices of GSFC's Minority University - Space Interdisciplinary Network (MU-SPIN) Program. The Offices of Equal Opportunity Programs, Space Science, and Mission to Planet Earth collaboratively provide funding and oversight for the GSFC MU-SPIN Program.

NASA Headquarters Program Offices, NASA Installations 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 assist in other facets of program implementation. Students and principal investigators involved in IRA (NRTS) spend time on-site at the Installations and JPL throughout the year.

The goal of the **HBCU Principal Investigator (PI) Awards** for Research is to provide faculty at HBCU's early in their careers, with an opportunity to integrate the research and education components with the unique mission requirements of a specific NASA Installation or JPL. By involving HBCU faculty and students, the Agency hopes to increase the interest of traditionally underrepresented communities in the Agency's mission and enhance a broader array of America's citizenry in the NASA-sponsored research community.

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, NASA Installations and JPL. Other strategies include: (1) Have discipline-related personnel at Headquarters and the NASA Installations and JPL be responsible for serving as points of contact for faculty interested in pursuing an award in this category; (2) Place responsibility for conducting the technical evaluations and making recommendations to Headquarters for funding consideration on the interested NASA Installation or JPL; (3) Provide funding to the nominating NASA Installation or JPL to make PI Awards for Research: and (4) Hold the NASA Installation or JPL responsible for managing the awards.

Under this category (PI), each fiscal year HBCU's are invited to submit proposals for the Faculty Awards for Research (FAR). The FAR provides for competitive peer review selection of outstanding and promising engineering, physical and life science-tenured and tenure-track faculty at minority institutions early in their academic careers who are capable of contributing to the Agency's research objectives and who have limited past NASA research grant experience. This award provides faculty members with sufficient research support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the transition toward achieving competitive awards in the Agency's mainstream research processes.

The **HBCU Mathematics and Science Awards** focus on strengthening the capacity of HBCU's to provide excellence in mathematics, science, engineering and technology (MSET) training while increasing the participation and achievement of disadvantaged students in MSET fields at all levels of education.

MSET Awards contribute to the national education goals by supporting educational outreach projects at HBCU's that increase the number and strengthen the skills, knowledge, and interest of students in mathematics, science, and technology-based academic programs. MSET awards, which consist of both unsolicited awards and solicited awards such as the NASA Precollege Awards for Excellence in Mathematics, Science, Engineering and Technology (PACE/MSET), will accomplish the following:

- Provide students with the necessary academic preparation and motivation to successfully complete challenging college preparatory MSET courses.
- Heighten students' interest and awareness of career opportunities in MSET fields.
- Expose students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and other educational activities.
- Provide scholarships, fellowships, internships, research opportunities in NASA-related fields and other supportive services for undergraduate and graduate students, historically underrepresented in NASA related disciplines.

- Expand the number of teachers and strengthen their MSET skills to better prepare them to teach in middle and high schools that have substantial enrollments of disadvantaged students.

In addition to the award categories listed above, the OEOP has initiated a new program of **Partnership Awards** to "expand opportunities and enhance diversity in the NASA sponsored research and education community...(and) achieve a balance between the proportion of NASA funding received by minority institutions of higher education and other institutions of higher education." One of the goals of the Partnership Awards is to strengthen NASA Installations' and JPL's partnerships with HBCU's through projects which are unique and innovative, which fall outside of the usual MUREP competitive programs, and which have high potential for long-term support from other sources.

The NASA Installations and JPL have been invited to partner with Presidents of Minority Universities to submit concept papers to Headquarters for competitive review and selection in three different categories: research; education; or combination research and education. Selected concept papers are expected to culminate in an award to a HBCU. All concept papers must be responsive to the Agency's strategic direction; the Federal mandates related to HBCU's; and the NASA MUREP goals.

NASA has established Technical Review Committees (TRC) to provide technical guidance and on-site reviews to recipients of Institutional Research Awards and Research Center awards. NASA promotes collaboration between its HBCU-funded programs, the Installations and 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. This is done in an effort to promote future sustainability. Research Centers, IRA's and PI awards require substantial undergraduate and graduate student involvement in research projects. The mathematics and science awards are normally managed by personnel at the NASA Installations and JPL. NASA Headquarters Program Offices, NASA Installations and JPL support the HBCU program through direct funding, use of their facilities, and commitment of their personnel to serve on TRC's and assist in other facets of program implementation. Numerous students and PI's from HBCU's spend time on-site at the Installations and JPL throughout the year.

## MEASURES OF PERFORMANCE

Progress towards achieving HBCU program goals is monitored through assessing the research involvement and productivity of faculty and students in NASA programs at HBCU's. The following data reflects participation in NASA's MUREP for FY 1995 awards:

- 339 faculty-level investigators were involved in NASA-related research awards for Research Centers, Institutional Research Awards, Faculty Awards for Research and other awards to individual principal investigators;
- 291 graduate and 489 undergraduate students were involved in NASA-related research;
- 212 refereed papers or book chapters were published and 382 presentations at research conferences or seminars;
- $10.6 million of research funding was obtained from other sources by the seven HBCU Research Centers; and
- 6,700 teachers and students in summer MSET enrichment and prefreshman activities, and in Saturday Academies during the academic school year.

The metrics devised for the Uniform Outcomes Data instruments previously described were modeled on the outcomes data instruments developed for monitoring URC performance. Summary performance data is collected annually using these instruments. Each URC is monitored by a **NASA** TRC which makes an annual site visit to the university campus. For the Group 1 URC's, special review teams were assembled during FY 1996 to perform independent evaluations in conjunction with the URC 5-year continuation proposals. These teams were uniformly enthusiastic about the quality of research work being conducted and the level of student achievements.

**A** final summary of accomplishments over the first 5 years is not yet available: however, during the first 4 of those 5 years, the accomplishments included the following:

| **GROUP 1 URC's: 4-Year Outcomes (FY 1992 - FY 1995)** | **HBCU's (7 Institutions)** |
|---|---|
| **STUDENT OUTCOMES (Underrepresented Minority Students Only)** | |
| Bachelor's Degrees | 87 |
| Master's Degrees | 44 |
| Doctoral Degrees | 8 |
| **RESEARCH OUTCOMES** | |
| Refereed papers published or accepted | 365 |
| Funds leveraged from other sources | $41.7M |
| Funds leveraged per $1 of **NASA** MUREP funding invested | $1.13 |
| Patents applied for or awarded | 7 |
| Commercial Products developed | 0 |

Not **all** metrics are reported, as data collection is currently underway.

The Group 2 URC's showed substantial productivity during their first year of funding (FY 1996).including:

| **GROUP 2 URC's: First-Year Outcomes (FY 1995)** | **HBCU's (4 Institutions)** |
|---|---|
| **STUDENT OUTCOMES (Underrepresented Minority Students Only)** | |
| Bachelor's Degrees | 8 |
| Master's Degrees | 4 |
| Doctoral Degrees | 4 |
| Undergraduate Students Supported | 90 |
| Graduate Students Supported | 21 |
| **RESEARCH OUTCOMES** | |
| Refereed papers published or accepted | 50 |
| Funds leveraged from other sources | $0.9M |
| Funds leveraged per $1 of **NASA** MUREP funding invested | $0.17 |
| Patents applied for or awarded | 0 |
| Commercial Products developed | 0 |

Second-year performance data for Group 2 is being collected during FY 1997, but is not yet available.

The metrics devised for the Uniform Outcomes Data instruments described above for the URC's will be used as the outcomes data instruments for the IRA (Research) performance beginning in FY 1997. Summary performance data will be collected annually using these instruments. Each IRA (Research) is monitored by a NASA TRC which makes an annual site visit to the university campus. Additionally, special review teams will be assembled during FY 1997 to perform independent comprehensive evaluations for each project.

Additional metrics for the Institutional Research Award (NRTS) will be designed to capture the technology and education focus of these awards. Specific metrics will include:

1. the number of HBCU's, OMU's and public schools connected to the Internet;
2. the number of persons gaining access by such connections; and
3. the number of faculty, teachers and students trained to utilize the Internet to enhance research and educational outcomes.

In FY 1995, an outcomes survey of all *(FAR)* award recipients (which includes some IPI awards) was conducted. Based on the experience gained with this survey, a Uniform Outcomes Data collection process is being instituted in FY 1997. All MUREP-funded individual research awards must be responsive to metrics that track research outcomes (refereed publications, leveraged funding, patents, and commercial products). Vital process information, such as numbers of faculty and students supported, and the gross categories in which funds are spent, will also be collected. This will allow the formation of reports using benchmarking divisors (e.g., numbers of degrees awarded per dollar spent on students, or number of publications per faculty investigator).

HBCU Mathematics and Science Awards are continually evaluated through analysis of performance reports and on-site assessments conducted by external reviewers. Data on precollege program outcomes is gathered through an annual survey entitled, "Precollege and Bridge Programs Performance Report." Data gathered for education projects emphasize improvements in student performance. Short-term metrics will track increases in pre/post-test scores and increases in enrollment in mathematics and science preparatory courses for students in NASA programs. Long-term metrics will track the rates at which K-12 students in NASA programs enter college and obtain advanced degrees. In addition, data on the numbers of students and institutions supported will continue to be collected and reported.

## ISHMENTS AND PLANS

The special review teams assembled in FY 1996 to evaluate the first group of HBCU Research Centers returned reviews which exceeded expectations. The reviewers consistently cited high quality research work and exceptional student performance. As a result, all seven of these HBCU Research Centers will be funded for an additional 5 years (FY 1997 - FY 2001). For the first 5 years, each HBCU research center received up to $2M per year. These funds were deemed necessary to establish a research infrastructure capable of spawning long-term success in their research and education efforts. For the second 5 years, the funding will be reduced to a maximum of $1M per year per Research Center. This reduced funding level recognizes and encourages the movement of the HBCU Research Centers towards self-sufficiency through other funding sources.

The second group of HBCU Research Centers will enter their third year of funding during FY 1997. This group is funded at a maximum of $1.5M per year per Research Center for their first 3 years (including FY 1997). The planned funding will then drop to a maximum $1.0M per year per Research Center in FY 1998 and FY 1999.

The NASA Enterprise Program Offices provide base funding of $16.0M per year for the HBCU Research Centers. The funding levels shown for HBCU Research Centers under the minority university research and education line reflect only the amounts which MUREP must add to the Program Office base in order to meet the HBCU Research Center program requirements. This funding decreases by $2.0M in FY 1997 due to the decrease in funding levels for the first group of HBCU Research Centers as they enter their second 5 years. The funding decreases again by $1.7M in FY 1998 due to the planned decrease in funding levels for the second group of HBCU Research Centers as they enter their fourth year. The URC's have demonstrated substantial successes thus far: it is imperative to continue their funding in order to maximize the return on NASA's investment in these institutions.

IRA (NRTS) - 5 HBCU's received renewal awards in FY 1996 for NRTS. These NRTS encompass seven regions that cover the 50 states, Puerto Rico and the Virgin Islands. A minimum of two faculty/teacher/student regional training workshops per institution were held this year.

| University | Research Focus | Lead NASA Installation |
|---|---|---|
| Prairie View A&M University | Regional NRTS | Goddard Space Flight Center |
| Elizabeth City State University (ECSU) | Regional NRTS at ECSU | Goddard Space Flight Center |
| Morgan State University (MSU) | NRTS at MSU | Goddard Space Flight Center |
| South Carolina State University | NRTS | Goddard Space Flight Center |
| Tennessee State University (TSU) | NASA/TSU NRTS | Goddard Space Flight Center |

The PI Awards for Research at HBCU's increased to 149 awards between FY 1996 and FY 1997. FY 1997 funding for PI's at HBCU's will support nine third-year and 15 second-year FAR awards and continue NASA Installation PI awards. Ten new FAR awards will be selected.

Efforts will continue to have the majority of HBCU research selected for funding to be made through competitive peer review and merit selection processes. Through more involvement in processes similar to FAR, it is expected that 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 and disabled 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 1996, NASA outreach programs at 21 HBCU's involved 6,700 students in MSET enhancement activities. FY 1996 precollege awards increased significantly over FY 1995, with plans to continue to expand in FY 1997 and a decline in FY 1998. NASA MSET awards to HBCU's support partnerships with elementary and secondary schools, and industry. Through these partnership arrangements, disadvantaged precollege students are stimulated and challenged to excel in mathematics, science, engineering, and technology-based college preparatory courses.

In FY 1996, 177 students were supported through graduate researchers awards; 33 of those attended HBCU's. This included support for two new programs at Florida A&M and North Carolina A&T State Universities, supporting 30 graduate students in engineering. These numbers are expected to remain constant through FY 1997. In FY 1998, these numbers are expected to decline as support for students at non-minority institutions is phased out.

In FY 1996, 300 students were supported through undergraduate scholars awards; 140 of these attended 12 HBCU's. The pipeline of undergraduate students majoring in the physical and life sciences and engineering coming from this program is expected to substantially and positively impact NASA's and the aerospace industry's human resources needs. These students are also being targeted for graduate level studies and research careers in the fields of science and engineering. The recipients of undergraduate awards are expected to feed into the graduate researchers programs, especially considering the relationships the students develop with the NASA Installations and JPL as a result of being an undergraduate scholar. Each year the graduating class will be replaced by new selections, thereby keeping the total number of participants fairly constant over the next several years.

In FY 1996, NASA supported 5 MASTAP awards at HBCU's for $200,000 each. During FY 1997, 8 MASTAP ( 5 HBCU's) and 17 PACE Awards (9 HBCU's) are expected to receive continuation funding. No new PACE or MASTAP Awards will be made in FY 1997. In FY 1998, 8 MASTAP (5 HBCU's) and 17 PACE (9 HBCU's) will receive the planned third and final year of funding. Competitive opportunities for new FY 1997 educational awards will be provided under the announcement of opportunity for Partnership Awards.

## BASIS OF THE FY 1998 FUNDING REQUIREMENT

### OTHER MINORITY UNIVERSITIES

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| University Research Centers.. | 1,700 | 1,800 | 400 |
| Institutional Research Awards | 2,700 | 2,200 | 2,300 |
| Principal Investigator Awards.. | 6,600 | 7,300 | 4,800 |
| Math Science and Education Awards | 9,400 | 7,800 | 7,900 |
| Partnership Awards.. | -- | 4.400 | -- |
| Total | 20,400 | 23,500 | 15,400 |

### PROGRAM GOALS

The goal of NASA's OMU program is to increase the opportunities for HSI's, Tribal Colleges 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

In the House and Senate Reports accompanying the FY 1985 VA-HUD-Independent Agencies Appropriations Act (P.L. 98-371), Congress established building relationships between NASA and minority institutions of higher education as a priority. Language included in both reports (House Report 98-803 and Senate Report 98-506) directed NASA 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..." To provide greater emphasis on this congressional mandate, NASA established the OMU Program in 1991. Since that time, Executive Orders and congressional reports have provided additional guidance to the Agency to strengthen its research and education programs with other minority universities. In 1994, Executive Order 12900 (February 22, 1994) mandated that agencies increase Hispanic American participation in Federal education programs where Hispanic Americans currently are underserved, and Executive Order 12928 (September 16, 1994) directed Federal agencies to promote procurement with, ."...Historically Black Colleges and Minority Institutions." Congress directed funding increases for the HSI's. Additionally, congressional direction was provided to NASA in the Conference report accompanying the FY 1995 VA-HUD-Independent Agencies Appropriations Act (P.L. 103-327) to establish NASA research centers at the HSI's.

NASA responded to the early congressional and Executive Branch direction by formulating a 5-year plan for the OMU program in FY 1991 to strengthen the Agency's research initiatives at other minority universities. This plan consists of three phases:

(1) individual principal investigator research awards; (2) institutional research awards; and (3) teacher training and student programs focusing on NASA-related disciplines. The plan addressed all institutions with significant minority populations other than HBCU's. The OMU plan was expanded in FY 1993, when the NASA Administrator signed a plan to strengthen the Agency's relationships with HSI's. The direction received from Congress and the Executive Branch is reflected in the current program plan for **OMU's.**

President Clinton signed Executive Order 13021 "Tribal Colleges and Universities," on October 19, 1996, to strengthen the relationship between Federal agencies and Tribal Colleges and Universities. In response to the Tribal Colleges Executive Order, NASA will be developing a 5-year plan of action and will submit annual accomplishment reports to the White House Initiatives Office.
NASA strategies for achieving the goals of the OMU Program reflect those established in the HBCU Program. However, because of the differences in the evolution of minority institutions and the particularities of Federal mandates for HBCU's Hispanic Americans, and Tribal Colleges and Universities, NASA's approach and implementation plan have been adjusted to take these factors into consideration. For example, the Federal mandate for Hispanic Americans directs Federal agencies to "....improve educational outcomes for Hispanic Americans participating in Federal education programs...". The Executive Order on Tribal Colleges and Universities reaffirms the special relationship of the Federal Government to American Indians and Alaskan Natives, and outlines six specific areas of emphasis for Federal Agency's attention. ***As*** a result, the Agency has placed greater emphasis on mathematics and science awards than on institutional research awards. The strategies for achieving goals under NASA's OMU program are identified below in priority order:

1. Mathematics and Science Awards:
2. Partnership Awards:
3. Individual Principal Investigator Awards:
4. Institutional Research Awards: and
5. Research Center Awards.

The NASA **OMU University Research Centers Awards** program began in FY 1995 with the establishment of three OMU Research Centers designed to achieve a broad-based, competitive aerospace research capability among the Nation's OMU'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 of OMUs in mainstream research; and increase the production of students, who are U.S. citizens and who have historically been underrepresented, with advanced degrees in NASA-related fields.

Funding for the OMU research centers is primarily provided by the Strategic Enterprises.

OMU Research Centers:

| University | Research Focus | Lead NASA Installation |
|---|---|---|
| University of New Mexico | Center for Autonomous Control Engineering | Ames Research Center |
| University of Texas at El Paso | Pan American Center for Earth and Environmental Studies | Goddard Space Flight Center |
| University of Puerto Rico at Mayagiiez | Tropical Center for Earth and Space Studies | Goddard Space Flight Center |

In order to foster closer ties between the OMU research centers and NASA, a Lead NASA Installation has been designated for each URC. Beginning with the FY 1997 renewals, the Lead Installations will become responsible for directly managing the URC's cooperative agreements, and for increasing the HBCU's involvement in ongoing NASA research and development activities. Collaborations with other NASA Installations, industry, and other universities will continue to be strongly encouraged.

The OMU Research Centers, along with the HBCU research centers, have formed a National Alliance of NASA University Research Centers (NANURC). This Alliance has established an annual National Conference of the University Research Centers, created pathways for developing greater collaborations between the University Research Centers, and is exploring avenues for increasing the number of advanced degrees being awarded to underrepresented minority students. NASA is strongly supportive of this concept and is actively working with the Alliance to further develop and strengthen their organization.

The goal of the **OMU Institutional Research Awards (IRA)** is to improve academic, scientific and technology infrastructure and broaden the NASA-related science and technology base at OMU'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. The second IRA (Network Resources and Training Sites [NRTS]) were open to both OMU's and HBCU's. The objectives of the IRA (Research) are: to strengthen and improve core research areas of significance to the NASA mission; to increase the number of students who are U.S. citizens conducting space research and working in NASA-related disciplines: and to strengthen the research environment of eligible institutions and the capability of individuals by supporting the institutional infrastructure (through the acquisition of research equipment), faculty research, disadvantaged U.S. citizens who are undergraduate and graduate student researchers, and technology transfer to the market place and to minority communities. The IRA (NRTS) award is designed to improve the in-house capability of OMU's 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 OMU'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 (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, disadvantaged U.S. citizens who are undergraduate and graduate student researchers: and (4) technology transfer to the market place and to minority communities. To enhance the achievement of the above strategies, NASA has established an Agency-wide TRC for each of the selected IRA (Research) award recipients. The NASA TRC's are responsible for providing technical guidance to IRA (Research) recipients. NASA promotes collaboration between its funded IRA institutions, the Installations, 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. This is done in an effort to promote future sustainability. IRA awards require substantial undergraduate and graduate student involvement in research projects.

The strategies for achieving the IRA (NRTS) goals include: (1) designating a lead OMU as an NRTS; and (2) holding the lead OMU accountable for providing internet connectivity to a minimum number of other OMU's and public schools, and for training students, faculty and teachers to build computers, maintain and effectively utilize the internet to compliment teaching and

research collaborations and delivery. The lead NASA Installation, Goddard Space Flight Center (GSFC),manages the IRA (NRTS) under the auspices of GSFC's Minority University - Space Interdisciplinary Network (MU-SPIN) Program. The Offices of Equal Opportunity Programs, Space Science, and Mission to Planet Earth collaboratively provide funding and oversight for the GSFC MU-SPIN Program.

NASA Headquarters Program Offices, NASA Installations and JPL support both IRA programs through direct funding, use of their facilities, and commitment of their personnel to serve on TRC's and assist in other facets of program implementation. Students and principal investigators involved in both the IRA (Research) and IRA (NRTS) spend time on-site at the Installations and JPL throughout the year.

**IRA (Research)**

| Program | University | Research Focus | Lead NASA Installation |
|---|---|---|---|
| OMU | California State University - Los Angeles | The Use of Decentralized Control in Design of a Large Segmented Space Reflector | Jet Propulsion Laboratory |
| OMU | Florida International University | High Performance Database Management with Application to Earth Sciences | Goddard Space Flight Center |
| OMU | University of Puerto Rico-Rio Piedras | Land Management in the Tropics and Its Effects on the Global Environment | Marshall Space Flight Center |
| OMU | The City College of New York | Tunable Solid State Laser and Optical Imaging | Langley Research Center |
| OMU | New Mexico Highlands University | Alliance for Nonlinear Optics | Marshall Space Flight Center |

**IRA (NRTS)**

| Program | Universitv | Research Focus | Lead NASA Installation |
|---|---|---|---|
| OMU | The City College of New York | An Urban Collaboration for Network Connectivity and Internet Access | Goddard Space Flight Center |
| OMU | University of Texas at El Paso (UTEP) | UTEP NRTS | Goddard Space Flight Center |

The goal of the **OMU Principal Investigator (PI) Awards for Research is** to provide faculty at OMU's, early in their careers, with an opportunity to integrate the research and education components of their careers with the unique mission requirements of a specific NASA Installation or JPL. By involving OMU faculty and students, the Agency hopes to increase the interest of traditionally underrepresented communities in the Agency's mission and enhance a broader array of America's citizenry in the NASA-sponsored research community.

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, NASA Installations and JPL. Other strategies include: (1) Have discipline-related

personnel at Headquarters and the NASA Installations and JPL be responsible for serving as points of contact for faculty interested in pursuing an award in this category: (2)Place responsibility for conducting the technical evaluations and making recommendations to Headquarters for funding consideration on the interested NASA Installation or JPL: (3) Provide funding to the nominating NASA Installation or JPL to make PI Awards for Research: and (4) Hold the NASA Installation or JPL responsible for managing the awards.

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MSET Awards contribute to the national education goals by supporting educational outreach projects at OMU's that increase the number and strengthen the skills, knowledge, and interest of students in mathematics, science, and technology-based academic programs. MSET awards, which consist of both unsolicited awards and solicited awards such as the "NASA Precollege Awards for Excellence in Mathematics, Science, Engineering and Technology" (PACE/MSET), will accomplish the following:

- Provide students with the necessary academic preparation and motivation to successfully complete challenging college preparatory MSET courses:
- Heighten students' interest and awareness of career opportunities in MSET fields.
- Expose students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and other educational activities.
- Provide scholarships, fellowships, internships, research opportunities in NASA-related fields and other supportive services to Graduate and Undergraduate students historically underrepresented in NASA-related disciplines..
- Expand the number of teachers and strengthen their MSET skills to better prepare them to teach in middle and high schools that have substantial enrollments of disadvantaged students.

In addition to the award categories listed above and consistent with congressional direction and funding, the OEOP has initiated **OMU Partnership Awards** 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." One of the goals of the Partnership Awards is to strengthen NASA Installations' and JPL's

partnerships with OMU's through projects which are unique and innovative, which fall outside of the usual MUREP competitive programs, and which have high potential for long-term support from other sources.

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## MEASURES OF PERFORMANCE

Progress towards achieving the OMU program goals is monitored through assessing the research involvement and productivity of faculty and students in NASA programs at OMU's. The following data reflects participation in NASA's MUREP for FY 1995 awards:

- 95 faculty-level investigators were involved in NASA-related research awards for Research Centers, Institutional Research Awards, Faculty Awards for Research and other awards to individual principal investigators;
- 104 graduate and 125 undergraduate students were involved in research activities at OMU's:
- More than 117 referred papers or book chapters were published and 140 presentations were made at research conferences or seminars;
- 32,886 precollege teachers and students, including students with disabilities challenged to excel in mathematics and science courses offered through precollege educational awards.

The metrics devised for the Uniform Outcomes Data instruments previously described were modeled on the outcomes data instruments developed for monitoring URC performance. Summary performance data is collected annually using these instruments. Each URC is monitored by a NASA Technical Review Committee which makes an annual site visit to the university campus. The OMU URC's showed substantial productivity during their first year of funding (FY 1996), including:

| GROUP 2 URC's: First-Year Outcomes (FY 19951 | OMU's (3 Institutions) |
|---|---|
| **STUDENT OUTCOMES (Underrepresented Minority Students Only)** | |
| Bachelor's Degrees | 29 |
| Master's Degrees | 5 |
| Doctoral Degrees | 0 |

| | |
|---|---|
| Undergraduate Students Supported | 65 |
| Graduate Students Supported | 43 |

**RESEARCH OUTCOMES**

| | |
|---|---|
| Refereed papers published or accepted | 45 |
| Funds leveraged from other sources | $1.4M |
| Funds leveraged per $1 of NASA MUREP funding invested | $0.34 |
| Patents applied for or awarded | 1 |
| Commercial Products developed | 0 |

The metrics devised for the Uniform Outcomes Data instruments described above for the University Research Centers (URC's)will be used as the outcomes data instruments for the IRA (Research) performance beginning in FY 1997. Summary performance data will be collected annually using these instruments. Each IRA (Research] is monitored by a NASA Technical Review Committee which makes an annual site visit to the university campus.

Additional metrics for the Institutional Research Award (NRTS) will be designed to capture the technology and education focus of these awards. Specific metrics will include:

1.) the number of OMU's and public schools connected to the Internet:
2.) the number of persons gaining access by such connections: and
3.) the number of faculty, teachers and students trained to utilize the Internet to enhance research and educational outcomes.

During the first-year IRA (Research) period of performance, FY 1995, 44 faculty-level researchers, 19 graduate and 29 undergraduate U.S. citizen students were involved in NASA-related research with the six IRA's. The number of investigators remained fairly level in FY 1996, the number of students increased (27 graduate and 33 undergraduate), and more than 70 refereed papers and/or book chapters were published and more than 80 presentations were made at research conferences and seminars (the first year this data was compiled). There were 2 OMU IRA (NRTS) renewal awards in FY 1996 for N K E . These N K E encompass seven regions that cover the 50 states, Puerto Rico and the Virgin Islands. During the first year of this award, more than 56 higher education institutions are supported directly through this award and 24 partner public schools. A minimum of two faculty/teacher/student regional training workshops were held this year.

In FY 1995, an outcomes survey of all (FAR) award recipients (which includes some IPI awards) was conducted. Based on the experience gained with this survey, a Uniform Outcomes Data collection process is being instituted in FY 1997. All MUREP-funded individual research awards must be responsive to metrics that track research outcomes (refereed publications, leveraged funding, patents, and commercial products). Vital process information, such as numbers of faculty and students supported, and the gross categories in which funds are spent, will also be collected. This will allow the formation of reports using benchmarking divisors (e.g., numbers of degrees awarded per dollar spent on students, or number of publications per faculty investigator).

OMU Mathematics and Science Awards are continually evaluated through analysis of performance reports and on-site assessments conducted by external reviewers. Data on precollege program outcomes is gathered through an annual survey entitled, "Precollege and Bridge Programs Performance Report." Data gathered for education projects emphasize improvements in student performance. Short-term metrics will track increases in pre/post-test scores and increases in enrollment in mathematics and science preparatory courses for students in NASA programs. Long-term metrics will track the rates at which K-12 students in NASA programs enter college and obtain advanced degrees. In addition, data on the numbers of students and institutions supported will continue to be collected and reported.

## ISHMEN AND PLANS

The OMU research centers will enter their third year of funding during FY 1997. This group is funded at a maximum of $1.5M per year per research center for their first 3 years (including FY 1997). The planned funding will them drop to a maximum of $1.OM per year per research center for FY 1998 and FY 1999.

The NASA Enterprise Program Offices provide base funding of $2.6M per year for the OMU research centers. The funding levels shown for OMU research centers under the minority university research and education line reflect only the amounts which MUREP must add to the Program Office base in order to meet the OMU research center program requirements. The funding decreases by $1.4M in FY 1998 due to the planned decrease in funding levels for the OMU research centers as they enter their fourth year.

IRA (Research) - six OMU's were selected to receive the first IRA (Research) awards in FY 1994. One OMU award was canceled when substantial changes was made in the scope and direction of their selected research. The continuing IRA (Research) recipients will be subjected to a comprehensive peer review during FY 1997. This review will be conducted on-site by internal and external peer reviewers to collect not only the quantitative data but to also ascertain the qualitative results achieved. It is planned that all will be eligible for continuation funding in FY 1997 and FY 1998.

| Program | Universitv | Research Focus | Lead NASA Installation |
|---|---|---|---|
| OMU | California State University - Los Angeles | The Use of Decentralized Control in Design of a Large Segmented Space Reflector | Jet Propulsion Laboratory |
| OMU | Florida International University | High Performance Database Management with Application to Earth Sciences | Goddard Space Flight Center |
| OMU | University of Puerto Rico-Rio Piedras | Land Management in the Tropics and Its Effects on the Global Environment | Marshall Space Flight Center |
| OMU | The City College of New York | Tunable Solid State Laser and Optical Imaging | Langley Research Center |
| OMU | New Mexico Highlands University | Alliance for Nonlinear Optics | Marshall Space Flight Center |

IRA (NRTS) - 2 OMU's received renewal awards in FY 1996 for NRTS. These NRTS encompass seven regions that cover the 50 states, Puerto Rico and the Virgin Islands. A minimum of two faculty/teacher/student regional training workshops per institution were held this year.

| Program | University | Research Focus | Lead NASA Installation |
|---|---|---|---|
| OMU | The City College of New York | An Urban Collaboration for Network Connectivity and Internet Access | Goddard Space Flight Center |
| OMU | University of Texas at El Paso (UTEP) | UTEP NRTS | Goddard Space Flight Center |

The PI Awards for Research at OMU's increased slightly in FY 1996 to 116 awards which included 15 third-year. three second-year, five new FAR awards and a continuation of other PI's. FY 1997 will increase to 126 awards, which include three third-year, seven second-year, 10 new FAR awards, and a continuation of other PI awards at OMU's.

In FY 1998, efforts will continue to have the majority of OMU research selected for funding to be made through competitive peer review and merit selection processes. Through more involvement in processes similar to FAR, it is expected that 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 and disabled 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 1996, 177 students were supported through graduate researchers awards; 20 of those students attended 4 OMU's. These numbers are expected to remain constant through FY 1997. In FY 1998, these numbers are expected to decline as support for students at non-minority institutions is phased out.

In FY 1996, the NASA Hispanic Education Program has impacted over 7,500 Hispanic students through programs at 23 Hispanic-Serving Institutions (HSI). These programs form an educational pipeline providing a broad range of opportunities for students to participate starting in grades K- 12, and continuing to precollege, college, graduate school and to major research centers conducting NASA-related studies. In FY 1996, NASA added five new institutions to the Hispanic Education program and three states where it did not have programs before. Also in FY 1996, NASA initiated a very meaningful relationship with the Hispanic Association of Colleges and Universities (HACU) by initiating *Proyecto* Access, a consortium which brings HACU the preeminent organization representing HSI's together with seven institutions of higher education to conduct 8-week summer programs.

In FY 1996, three new Precollege Awards for Excellence in Math, Science, Engineering and Technology were awarded to HSI's. In FY 1996, NASA supported 3 MASTAP Awards at OMU's for $200,000 each. During FY 1997, 8 MASTAP (6 OMU's) and 17 PACE Awards (8 OMU's) are expected to receive continuation funding. No new PACE or MASTAP Awards will be made in FY 1997. In FY 1998, 8 MASTAP (3 OMU's) and 17 PACE (8 OMU's) will receive the planned third and final year of funding. Competitive opportunities for new FY 1997 educational awards will be provided under the announcement of opportunity for Partnership Awards.

In FY 1996, NASA increased support for Tribal Colleges and Universities by over $300,000 through three new initiatives and expanded outreach to nine Tribal Colleges. NASA has initiatives with 10 mainstream universities for the purpose of increasing the number of Native American students enrolled in MSET curricula. In FY 1996, NASA provided outreach to over 3,000 Native American students from kindergarten through graduate school. Enrollment and retention rates have risen significantly in NASA supported programs.

In FY 1998, efforts will continue to have the majority of OMU education awards selected for funding to be made through competitive peer review and merit selection process.

**Mission Support**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 1998 ESTIMATES

## GENERAL STATEMENT

### GOAL STATEMENT

The Mission Support appropriation provides funding for agencywide activities which are critical to NASA's mission success. This includes funding to: support NASA's civil service workforce: to provide critical space tracking and communications capabilities required by all missions: to conduct safety and quality assurance activities; and for activities to preserve NASA's core infrastructure.

### FOR GOALS

Funding included in the Mission Support appropriation supports agency-wide activities which touch all of NASA's programs:

Safety, Reliability and Quality Assurance: 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.

Space 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. This includes the Tracking and Data Relay Satellite System (TDRSS), and the telecommunications system which provides for real time transmission of data, video and voice information between and among NASA installations.

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 includes funding for the repair, rehabilitation, modification and construction of the institutional facilities, the environmental compliance and restoration program, and the advanced planning of facilities and design of future facilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 1998 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| **MISSION SUPPORT** | **2,487.3** | **2,564.3** | **2,513.2** |
| SAFETY, RELIABILITY AND QUALITY ASSURANCE | 39.0 | 38.8 | 37.8 |
| SPACE COMMUNICATION SERVICES | 255.4 | 277.7 | 245.7 |
| RESEARCH AND PROGRAM MANAGEMENT | 2047.9 | 2092.5 | 2070.3 |
| CONSTRUCTION OF FACILITIES | 145.0 | 155.3 | 159.4 |

# 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: space communications activities including operations, production and services: maintenance; construction of facilities including repair. rehabilitation. 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 therefor. as authorized by 5U.S.C.5901-5902: travel expenses: purchase. lease. charter. maintenance, and operation of mission and administrative aircraft: not to exceed $35,000 for official reception and representation expenses; and purchase (not to exceed 33 for replacement only) and hire of passenger motor vehicles: [$2,562,200,000] ***$2,513,200,000***, to remain available until September 30. [1998] 1999. For necessary expenses of certain space projects under development. 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 1998. $157,500,000; for fiscal year 1999,$120,400,000; for fiscal year 2000, $58,000,000; for fiscal year 2001, **$70,000,000**; for fiscal year 2002, $98,200,000; and for fiscal year 2003, $52,600,000. ***[Departments of Veterans Affairs and Housing and Urban Development. and Independent Agencies Appropriations Act, 1997.)***

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

| | BUDGET PLAN | | |
|---|---|---|---|
| | FY 1996 | FY 1997 | FY 1998 |
| **MISSION SUPPORT** | **110.8** | **131.7** | **133.7** |
| SAFETY, RELIABILITY AND QUALITY ASSURANCE | **0.7** | 0.5 | **0.5** |
| SPACE COMMUNICATION SERVICES | 61.5 | 63.6 | 67.4 |
| RESEARCH AND PROGRAM MANAGEMENT | 46.6 | 66.1 | 64.3 |
| CONSTRUCTION OF FACILITIES | 2.0 | 1.5 | 1.5 |

## NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## FISCAL YEAR 1998 ESTIMATES
## SUMMARY OF RESOURCES REQUIREMENTS

## DISTRIBUTION OF MISSION SUPPORT BY INSTALLATION
## (IN THOUSANDS OF REAL YEAR 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 | Lewis Research Center | Goddard Space Flight Center | Jet Propulsion Lab | Head-quarters |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Safety. Reliability and Quality Assurance | 1996 | 39.025 | 4,509 | 1.959 | 3.710 | 495 | 5.129 | 197 | 3,955 | 4.027 | 4.655 | 8.842 | 1.547 |
| | 1997 | 38,800 | 4.330 | 1.150 | 3.170 | 350 | 6.970 | 430 | 2.150 | 4,120 | 4,940 | 7.740 | 3,450 |
| | 1998 | 37,800 | 5,200 | 900 | 2,300 | 200 | 6,900 | 400 | 5,200 | 2,500 | 4,800 | 5,600 | 3,800 |
| Space Communication Services | 1996 | 255,400 | 0 | 0 | 54,800 | 0 | 150 | 0 | 0 | 3,200 | 189.393 | 4.955 | 2,902 |
| | 1997 | 277,700 | 3,800 | 0 | 55,400 | 0 | 0 | 0 | 0 | 17,900 | 191,600 | 6,000 | 3,000 |
| | 1998 | 245,700 | 0 | 0 | 79,000 | 0 | 0 | 0 | 0 | 50,500 | 109,000 | 4,300 | 2,900 |
| Research and Program Management | 1996 | 2,047,974 | 352,300 | 236,300 | 276,600 | 31,400 | 156,500 | 39,500 | 200,000 | 195,700 | 317.774 | 0 | 241,900 |
| | 1997 | 2,092,500 | 343,600 | 230,100 | 290,400 | 43,000 | 163,200 | 48,400 | 206,700 | 196,600 | 336,700 | 0 | 233,800 |
| | 1998 | 2,070,300 | 338,100 | 221,600 | 292,700 | 43,100 | 166,100 | 55,100 | 212,800 | 190,200 | 332,500 | 0 | 218,100 |
| Construction of Facilities | 1996 | 126.470 | 13,955 | 13,100 | 18.030 | 7,400 | 11.830 | 4.170 | 8.545 | 19.265 | 13.875 | 16,300 | 0 |
| | 1997 | 131,400 | 14,000 | 8,200 | 20,500 | 4,600 | 9,300 | 12,700 | 7,200 | 16,600 | 20,300 | 18,000 | 0 |
| | 1998 | 131,700 | 7,000 | 18,100 | 24,700 | 7,500 | 8,300 | 6,400 | 6,100 | 17,800 | 18,100 | 17,700 | 0 |
| Undistributed: Various locations | 1996 | 18,470 | | | | | | | | | | | |
| | 1997 | 23,900 | | | | | | | | | | | |
| | 1998 | 27,700 | | | | | | | | | | | |
| Total Construction of Facilities | 1996 | 144,940 | | | | | | | | | | | |
| | 1997 | 155,300 | | | | | | | | | | | |
| | 1998 | 159,400 | | | | | | | | | | | |
| TOTAL MISSION SUPPORT | 1996 | 2,487,339 | 370,764 | 251,359 | 353,140 | 39,295 | 173,609 | 43,867 | 212,500 | 222.192 | 525,697 | 30,097 | 246,349 |
| | 1997 | 2,564,300 | 365,730 | 239,450 | 369,470 | 47.950 | 179.470 | 61.530 | 216.050 | 235.220 | 553,540 | 31,740 | 240,250 |
| | 1998 | 2,513,200 | 350,300 | 240,600 | 398,700 | 50,800 | 181,300 | 61,900 | 224,100 | 261,000 | 464,400 | 27,600 | 224,800 |

Safety, Reliability and
Quality Assurance

**MISSION SUPPORT**

**FISCAL YEAR 1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF SAFETY AND MISSION ASSURANCE**
**OFFICE OF THE CHIEF ENGINEER**

**SAFETY, RELIABILITY, MAINTAINABILITY, AND QUALITY ASSURANCE**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Policy. oversight. and standards | 13.175 | 14.900 | 13.600 |
| Quality management | 9.650 | 10.000 | 7.800 |
| Software assurance | 6.000 | 6.300 | 5.500 |
| Engineering | 10.200 | 7.600 | 10,900 |
| Total | 39.025 | 38.800 | 37.800 |
| Distribution of Program Amount by Installation | | | |
| Johnson Space Center | 4.509 | 4.330 | 5.200 |
| Kennedy Space Center | 1.959 | 1.150 | 900 |
| Marshall Space Flight Center | 3.710 | 3.170 | 2.300 |
| Stennis Space Center | 495 | 350 | 200 |
| Ames Research Center | 5.129 | 6.970 | 6.900 |
| Dryden Flight Research Center | 197 | 430 | 400 |
| Langley Research Center | 3.955 | 2.150 | 5.200 |
| Lewis Research Center | 4.027 | 4.120 | 2.500 |
| Goddard Space Flight Center | 4.655 | 4.940 | 4.800 |
| Jet Propulsion Laboratory | 8.842 | 7.740 | 5.600 |
| Headquarters. | 1.547 | 3.450 | 3,800 |
| Total | 39.025 | 38,800 | 37,800 |

**OFFICE OF SAFETY AND MISSION ASSURANCE**
**OFFICE OF THE CHIEF ENGINEER**

**SAFETY RELIABILITY, MAINTAIN AND QUALITY ASSURANCE**

## PROGRAM GOALS

NASA's Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) program invests in the safety and success of all NASA programs. The SRM&QA program develops insight into NASA's programs and performs independent oversight that contributes to program safety and success. The program develops and promulgates necessary NASA-wide safety and risk management policies, standards, and guidelines. Up-front quality management activities focus on reducing costs, improving safety and reliability, including the development and application of SRM&QA tools to support better, faster, cheaper program development. Software assurance activities include the implementation of NASA's software assurance improvement program; development of tools and techniques: and oversight of the performance of independent verification and validation (IV&V) for critical flight, ground control, and robotics system software. The SRM&QA program develops NASA-wide engineering policies, standards, and guidelines: promotes the use of industry and international standards for spaceflight systems: sponsors the development and demonstration of methodologies for improved design, test, and validation of systems and enhanced systems engineering capability: supports independent review of proposed and on-going programs; provides support to the NASA Program Management Council (PMC): and, investigates advanced aerospace concepts.

## STRATEGY FOR ACHIEVING GOALS

The SRM&QA program supports the activities of the Office of Safety and Mission Assurance (OSMA) and the Office of the Chief Engineer (OCE). The OSMA advises the Administrator and provides leadership in promoting and ensuring the safety and quality of all NASA programs through oversight of NASA programs and development of Agency-wide Safety and Mission Assurance (S&MA) policies and standards. OSMA efforts in the Policy, Oversight and Standards: Quality Management: and Software Assurance programmatic areas assist NASA's Strategic Enterprises in accomplishing their goals in a safe and efficient manner. The OCE provides a focus for NASA's engineering discipline, oversees application, and improves NASA's practices and capabilities through targeted initiatives in the Engineering programmatic area. The Advanced Concepts program for conceptual study of new and unconventional aerospace ideas is also part of the Engineering area beginning in FY 1998.

The Policy, Oversight, and Standards area addresses specific safety and mission assurance needs in the new environment of better, faster, cheaper missions and provides safety oversight and flight readiness assessments for NASA programs. Documentation and analysis of NASA experience in the SRM&QA disciplines. mishap investigations, monitoring compliance with the Occupational Safety and Health Act, and emergency preparedness planning improve safety and risk management in NASA programs. NASA's implementation of the International Organization for Standards' family of international quality standards (ISO 9000), the NASA

Engineering and Quality Audit, and the Advanced Quality Practices program seek to improve the quality of NASA's contracted work.

The Quality Management area supports the early introduction of risk management and tailored safety, reliability and quality requirements into aerospace systems design and manufacture. The expected results are decreased lifecycle costs for NASA programs by reducing or eliminating costly redesign late in development and test, and increased probability of mission success. Specific efforts in qualification test methods: non-destructive evaluation (NDE) technologies: electrical, electronic, and electro-mechanical (EEE) parts and packaging: and flight performance support these goals. The Quality Management area also provides direct SRM&QA support to robotics, aeronautics, and expendable launch vehicle programs.

The Software Assurance program supports the development of software assurance standards, practices, and technology to evaluate flight system, mission control, and science data system software. The goal is assured, improved performance and reliability of the increasingly complex and critical facility, ground system, and flight system software used in NASA programs.

The Engineering area provides independent evaluation of engineering technical and policy issues and coordination of engineering capability development through NASA's Engineering Management Council. Development of NASA engineering standards and policies and the use of appropriate industry, national, and international standards will improve interoperability and reduce the costs of aerospace systems: while improved practices for systems engineering, structural analysis, and test methods will increase the reliability and effectiveness of NASA programs. The Langley Research Center (LaRC) will provide independent evaluation of proposed and on-going programs in support of the NASA PMC review process. The Advanced Concepts program provides an avenue for introducing new ideas for advanced aerospace architectural and systems concepts into NASA programs. The program's goal is to stimulate and evaluate concepts from both internal and external sources, and to ensure that ideas that show merit are considered for support by NASA program offices.

## MEASURES OF PERFORMANCE

| Title | Metric Description | FY 1996 Results |
|---|---|---|
| Independent Assessments, Oversight, and Reviews | Contribute to the safety and success of NASA missions by ensuring that programs have resolved all technical issues prior to flight. Evaluate adequacy of NASA SRM&QA and Engineering capabilities: independently assess critical NASA issues. | OSMA conducted oversight for 8 successful Shuttle flights and 6 successful spacecraft launches. OSMA conducted 9 Center functional self-assessment reviews, 7 independent spot checks and staff reviews at Centers, and an operational safety review at NASA Headquarters. |

| Title | Metric Description | FY 1996 Results |
|---|---|---|
| Mishap Prevention | Contribute to reducing the number of accidents at NASA facilities and lessening productivity losses. | NASA's FY 1995 lost time injury rate decreased 28% from FY 1994, to a 10-year low of 0.31 lost workdays per 200,000 hours worked. Safety-related property losses were $2.0 M, down from $2.9 M in FY 1994. FY 1995 is the last year for which complete data is available. |
| Systems Engineering | Improve and expand the use of integrated analytic methods to perform the systems engineering analyses required to define and optimize new missions and to ensure that development programs meet mission requirements. | A system requirements and interface verification methodology (PATHS) developed at the Johnson Space Center (JSC) has been applied to the Space Station and adopted by the Jet Propulsion Laboratory (JPL) as a design tool. |
| Quality Management | Support spacecraft projects and technology development by providing early risk management and quality studies for maximum benefit at project completion. | OSMA successfully implemented risk management approaches early in the lifecycle for the New Millennium program, Deep Space I mission and for microdevices technology development. OSMA completed an integrated, multi-Center mission assurance program for the Aeronautics High Speed Research program and initiated activities to develop a quality assurance program for the Advanced Subsonics Technology program. |
| Engineering Standards and Practices | Improve technical guidance for NASA programs by integrating demonstrated technologies and lessons learned into Agency-wide standards that increase commonality and interoperability of NASA aerospace systems. | NASA issued 6 standards for structural design and test that consolidate and improve on previously conflicting procedures. NASA Fracture Control Analysis tools were adopted by the Federal Aviation Administration (FAA) and the Air Force. |
| Safety and Quality Requirements and Standards | Replace NASA standards with US and international industry standards wherever possible. Develop NASA standards where required. Emphasize compliance and adoption of ISO 9000. Reduce cost of procuring flight and ground systems. | NASA adopted ISO 9000 as its quality standard: implementation in new contracts has begun. OSMA reduced NASA S&MA policy documents and handbooks from 55 to 30 (3,000 to 1,200 pages) and issued a Software Safety standard. |

| Title | Metric Description | FY 1996 Results |
|---|---|---|
| Advanced Concepts | Stimulate and evaluate advanced aerospace architectural and systems concepts to enable, enhance, and/or lower the costs of NASA missions. | Eight advanced concepts research projects were initiated with universities and private institutes. |
| Technology Evaluation | Evaluate reliability and improve utilization of advanced but maturing technologies through ground and flight demonstration. | Higher reliability laser initiated ordinance technology was demonstrated on two launch vehicles, including the commercial Pegasus vehicle. |
| Test Effectiveness | Provide environmental test data analyses correlated against flight performance to quantify specific guidance for tailoring test programs to specific mission requirements, thus enabling lower mission development costs for better, faster, cheaper spacecraft. | OSMA provided spacecraft projects with on-orbit flight performance results correlated against design, development, and mission processes to serve as guidance for future projects. OSMA also provided test program data correlated to specific science mission requirements for tailoring testing as part of the design and development validation process. |
| EEE Parts and Packaging | Qualify advanced parts and packaging technologies to reduce size and power requirements for spaceflight systems. Facilitate use of most reliable advanced components through development and use of parts selection databases. | Parts selection tools and radiation and qualification testing enabled selection of most reliable parts available for New Millennium missions. |
| Aerospace Batteries | Develop design guidance and qualify advanced battery chemistries: perform operational evaluation of flight battery systems. | OCE conducted life tests and flight-cycle simulations of battery cells for spacecraft and ISS. Management of the battery program is moved to the Office of Space Science in FY 1998. |
| Non-Destructive Evaluation (NDE) | Develop and certify improved NDE methods for aerospace manufacturing and operations. Reduce manufacturing and test costs by reducing teardowns, scrappage, and replacements caused by destructive testing. | An orbiter window defect analyzer was certified for production use. reducing costs and improving inspection confidence. An NDE approach for silicon nitride ball bearings for advanced turbopumps was developed. |

## TS AND PLANS

In FY 1996, standards were completed for orbital debris (including assessment software) and oxygen and hydrogen safety. A joint test program with the Japanese Space Agency, NASDA, on liquid oxygen and hydrogen explosion safety distances was completed. Assessments and evaluations included Center S&MA self-assessments, several hazardous facility assessments, the Mars Pathfinder Safety Evaluation Report, and an independent assessment of initial program risk management processes for the X-33. Probabilistic risk assessments were performed for the Soyuz Crew Escape Vehicle and ISS. Shuttle probability estimates were revised. The ISS IA developed an independent critical risk assessment matrix and performed special technical and programmatic assessments. Center implementation plans for ISO 9000 were developed, kickoff orientation delivered, and compliance gap analysis completed. Training courses were developed and piloted for Certified Quality Engineer, Certified Reliability Engineer, and Certified Quality Technician. Nineteen computer-based courses were developed in S&MA disciplines including NDE, contractor oversight, and performance-based contracting. A comprehensive on-line S&MA training catalog was also developed. Calibration standards for intrinsic voltage, and ultra-low and very high pressures were developed. Also, a pooled process for calibrating equipment at all Centers was instituted. A user-friendly lessons learned database was placed on the World-Wide Web, and alternative approaches to the current Failure Modes Effects Analysis/Critical Items List risk assessment were developed. Eight Shuttle flights were supported, and improved data collection techniques reduced S&MA costs for ground processing.

Product and mission assurance requirements were specifically tailored for Mars Pathfinder, Mars Rover, High Speed Research (HSR), and Advanced Subsonic Technology (AST); and S&MA was involved early in New Millennium program planning. NDE techniques for screening advanced turbopump silicon nitride ball bearings (ultrasonic), for composite pressure vessel certification and acceptance testing, and for composite debond detection (laser shearography) were developed. An automated orbiter window defect analyzer was developed and certified for field use.

Operations and maintenance funding for the Fairmont, WV, IV&V facility supported software assurance on Cassini, ISS, Shuttle, and Earth Observing System Data Information System. A pilot formal methods approach verified complete software assurance requirements for Cassini. Additionally, a quantitative software methods and measurements guidebook was baselined for Shuttle and the Space Operations Management Office. Moreover, software domain reuse principles were applied to wind tunnel control. Assurance techniques continue to be developed for complex software systems, and a software safety guidebook was produced.

In FY 1996, the OCE led the development of a qualification process to enhance the reliability of commercial launch services acquired by NASA and led the Pegasus XL Return to Flight Review Team's efforts to support program mission success. The OCE provided leadership to develop the NASA Implementation Plan for the Federal Laboratory Review; approved for NASA-wide application a series of structural design and test standards; and established a Center-led program to implement additional consolidation and upgrades of current engineering practices. The Design, Test, and Verification program extended the NASA fracture analysis methodology to aging aircraft problems through cooperative agreements with the FAA. This program also supported verification tests of the damage-reducing, force limited vibration technique to additional payloads and began planning for a Shuttle flight verification of the technique. The OCE Battery program conducted life tests and operational simulations of NiCd and NiH2 battery cells in support of spacecraft and Space Station qualification programs. JPL used the Battery Test Bed to

develop and verify power management and optimization techniques for on-orbit spacecraft. Eight competitively selected projects were initiated with Advanced Concepts Research Fellows at universities and private institutes. Topics included propulsion, inflatable structures, spacecraft architectures, electronic components, and robotics. Contracted studies to examine advanced concepts for highly reusable space transportation systems were initiated, and a "virtual research center" system was deployed.

In FY 1997. OSMA will conduct oversight for NASA's seven planned Space Shuttle flights. Transition to the Shuttle Flight Operations Contract (SFOC)will be supported, and an improved, low-cost, easy-to-use Problem Reporting and Corrective Action system will be completed. The ISS IA will continue to evaluate the program's technical health and capability to safely achieve its program objectives, including software IV&V, with co-funding from the Office of Space Flight. Significant lessons learned and reliability and test best practices will be collected and distributed throughout NASA. Risk management and assessment techniques will be developed, refined, and applied. Reliability-centered maintenance techniques and processes, an orbital debris hazard and risk mitigation process, and hydrogen fire detection and smoke movement modeling for high bays will be established. NASA, government, and private sector education and training courses will be identified and integrated into NASA's SRM&QA training and professional development curriculum. New courses will be initiated to cover gaps or advancing technology. Advanced quality concepts will allow routine use of private sector best practices, principles, and metrics to achieve comparable or improved safety, reliability, and quality at less cost. ISO 9000 will be fully integrated as NASA's baseline standard for quality management systems, and NASA Engineering and Quality Audits will be regularly employed.

Mission assurance support for New Millennium and other spacecraft and aeronautics programs such as High Speed Civil Transport and Advanced Subsonics will continue. Processes will be in place to develop appropriate S&MA requirements tailored to cost, schedule, and risk. Emphasis will be placed on test effectiveness and on correlating S&MA requirements with flight performance to provide real-time evaluation and feedback to the specific programs. Effectivetest programs incorporating test histories, flight performance, and flight results will be conducted. Advanced EEE parts and packaging techniques will be employed to develop qualification and test methods for fiber optics, micro-electro-mechanical systems, micro actuators, and sensors that determine quality and reliability issues. The space radiation effects program will determine microelectronic parts radiation tolerance.

Software assurance will continue to assure flight, ground control and robotics system software. Research initiatives *in* verification and validation techniques, tools, and training course development will be conducted. Verification and validation best practices will be identified and applied to mission critical software projects.

In FY 1997, in response to the decision to assign LaRC the responsibility for program analysis and evaluation, the OCE will expand the Langley Research Center (LaRC)mission concept and analysis capability. The LaRC, using it's broad systems analysis capabilities, will provide independent assessment of conceptual designs relative to design integrity, system/subsystem trades, life-cycle costs, schedule estimates, risk and risk mitigation approaches, and technology issues. The LaRC will lead the Agency's program evaluation (PMC reviews) by organizing and participating in inter-center Non-Advocate Review (NAR), Independent Annual Review (IAR), and Independent Readiness Review (IRR) teams. In addition, it will provide specialized technical analysis to support review areas of particular concern. The OCE Standards program will continue consolidation of internal standards and will expand cooperative projects with non-Government standards, developing organizations to increase NASA use and support of national and

international consensus standards. The Design, Test and Verification program will initiate projects applying probabilistic analysis techniques to structural design to improve design margin management and increase system assurance. The program will also complete assessment of the impact of chloro-flourocarbon replacement cleaners on lifetimes of precision mechanical systems such as scanners and gyroscopes. The OCE Applied Technology program will complete testing to evaluate solutions to failure modes of pyrotechnic operated valves. The Aerospace Battery program will complete technology evaluation and initiate cell tests for Li-ion battery systems: conduct performance testing and physical analysis for advanced NiCd. NiH2, and AgZn battery cells: and develop a stress test for NiH2 cell qualification procedure. The Advanced Concepts Program will be restructured to place more emphasis on soliciting external ideas and concepts. *An* External Advanced Concepts Institute will be established to provide a forum to stimulate and analyze external concepts for new systems approaches to NASA missions. Each Enterprise will establish a process for soliciting and evaluating relevant concepts from any source, and the "virtual laboratory" concept will be established at several Centers for faster, more effective concept evaluation.

The FY 1998 budget supports critical agency infrastructure to maintain safety and mission success with decreasing agency resources and dramatic changes in business practices. Specific safety and mission assurance needs in the new environment of better, faster, cheaper missions are addressed. Independent assessment of the Space Shuttle and ISS programs is maintained. OSMA will fully fund the ISS IA effort (including software), a change from prior years. Tools, techniques, and procedures are developed to replace audit-based oversight with insight. Process verification techniques and data will ensure process stability and capability. Assurance for better, faster, cheaper missions moves from rule-based to knowledge-based approaches. Acquisition reform goals of efficiency and effectiveness through the Single Process Initiative, ISO 9000, and Performance-Based Contracting (PBC) are supported. The Professional Development Initiative and related training course development responds to projected S&MA skill mix problems. The results of implementing ISO 9000, PBC, and other contracting initiatives will be evaluated. Seven Shuttle flights will be supported and the performance of the SFOC evaluated.

The test effectiveness program and techniques for trading risk will enable informed test planning for better, faster, cheaper missions and improved risk management. Development of advanced, unique NDE techniques and studies on probability of detection will support longer life aerospace components. Product assurance support for "Instruments on Chips" will help lead to dramatically lighter and lower power electronics. The EEE parts and packaging effort maintains the mission reliability of rapidly evolving semiconductor technologies by performing radiation screening for advanced new parts: establishing technology readiness for insertion of emerging technology into microspacecraft: enabling the selection of commercial-off-the-shelf devices for better, faster, cheaper spacecraft and instruments: and, providing assurance for **micro-electro-mechanical** systems devices.

The Software Assurance program will continue to research, develop, pilot, and evaluate standards, tools, techniques, and processes to ensure the safe and reliable performance of increasingly complex critical mission software.

In FY 1998, the OCE's Standards program will establish a "Preferred Standards" system for NASA that completes consolidation of design practices and integrates the use of national and international consensus standards in space system development, test and implementation. Continued development of international standards for space systems through ISO will assist international cooperation and enhance U.S. competitiveness. International Product Data Standards will be used in system design and analysis for structures, thermal systems, and optical systems. Improvements to design, test, and validation capabilities will focus on

improving analytic methods and tools for evaluation of structural design. The Aerospace Battery Technology program will be transferred to the Space Science Enterprise in FY 1998 to continue qualification of advanced chemistries and operational support and evaluation of flight battery systems. The LaRC will continue to independently assess advanced mission concepts and will assume full responsibility for supporting NASA Program Management Council reviews of proposed and ongoing programs. New and enhanced analytical methods and tools for Advanced Concepts will be incorporated at NASA Centers to enable simulation-based design, collaborative computing, and interactive design team studies. The External Advanced Concepts Institute will sponsor workshops and conferences to focus attention on promising new high-potential technology areas for future NASA missions.

Space
Communication
Services

**MISSION SUPPORT**

**FISCAL YEAR 1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF SPACE FLIGHT** **E COMMUNICATIONS SERVICES**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Space Network | 157,200 | 185,100 | 161,200 | MS 2-4 |
| Telecommunications | 98,200 | 92,600 | 84,500 | MS 2-8 |
| Total | 255,400 | 277,700 | 245,700 | |
| Distribution of Program Amount by Installation | | | | |
| Johnson Space Center | -- | 3,800 | -- | |
| Marshall Space Flight Center | 54,800 | 55,400 | 79,000 | |
| Ames Research Center | 150 | -- | -- | |
| Lewis Research Center | 3,200 | 17,900 | 50,500 | |
| Goddard Space Flight Center | 189,393 | 191,600 | 109,000 | |
| Jet Propulsion Laboratory | 4,955 | 6,000 | 4,300 | |
| Headquarters | 2,902 | 3,000 | 2,900 | |
| Total | 255,400 | 277,700 | 245,700 | |

**PROGRAM GOALS**

The Space Communications goal is to enable the conduct of the NASA strategic enterprises by providing telecommunications systems and services. Reliable electronic communications are essential to the success **of** every NASA flight mission, from planetary spacecraft to **the** Space Shuttle to aeronautical flight tests.

The National Space **Policy** stipulates that NASA will "seek to privatize or commercialize **its** space communications operations no later than 2005". The Space Operations Management Office(SOMO),located at the Johnson Space Center, manages the

telecommunication, 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 program is composed of Space Network and Telecommunications programs. These programs provide communications support to human space flight missions and low-Earth-orbital spacecraft and the Tracking and Data Relay Satellite (TDRS) system: to expendable launch vehicles and research aircraft: and for telecommunications interconnectivity among NASA flight support networks, project and the mission control centers, data processing centers, NASA Centers and facilities, contractor facilities, and investigator science facilities located throughout the nation and the world.

**STRATEGY FOR ACHIEVING** GOALS

The Space Communications program provides command, tracking and telemetry data services between the ground facilities and flight mission vehicles. The program also supports 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 integrated solutions to operational communications and information management needs common to all NASA strategic enterprises as well as NASA-wide telecommunications network services to support all of NASA's administrative communications needs.

The range of telecommunications systems and services are provided to conduct mission operations, enable tracking, telemetry, and command of spacecraft and sub-orbital aeronautical and balloon research flights. Additionally, services and systems are provided to facilitate data capture, data processing, and data delivery for scientific analysis. The program also provides the high speed computer networking, voice and video conferencing, fax, and other electronic mail services necessary to administer NASA programs.

These communications functions are provided through the use of space and ground-based antennas and network systems, mission control facilities, computational facilities, command management systems, data capture and telemetry processing systems, and a myriad of leased interconnecting communications systems ranging from phone lines and satellite links to optical fibers.

The program provides the necessary research and development to adapt emerging technologies to NASA communications needs. 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. The program also provides scheduling, network management and engineering, pre-flight communications test and verification, as well as flight system maneuver planning and analysis for selected missions. NASA's flight programs are supported through the study and coordination of data standards and

communication frequencies to be used in the future. 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.

Many science and exploration goals require inter-agency or international cooperation in order to be achieved. NASA's Space Communications assets are provided through collaborative agreements to other U.S. Government agencies, commercial space enterprises, and international cooperative programs. Consistent with the National Space Policy, NASA will purchase commercially available goods and services to the fullest extent feasible, and will not conduct activities with commercial application that preclude or deter commercial space activities.

The modernization of the original White Sands Ground Terminal, Cacique, was completed last year, and returned to operational service. With its twin, Danzante (Second TDFS Ground Terminal), these ground terminals provide fail-safe operations of the Space Network and its TDFS spacecraft. Initial planning and design of a remote ground terminal capability at Guam, extending the White Sands Ground Terminal capability by providing for coverage of the Zone of Exclusion, was completed in FY 1996. Development of the system will occur during FY 1997 and FY 1998, with completion of the system in FY 1998. The Space Network provides communications for the Space Transportation System, the Hubble Space Telescope (HST) astronomical observatory and many other NASA missions, as well as for non-NASA users on a reimbursable basis. The development of the Replenishment Tracking and Data Relay Satellites is on-going. The Telecommunications program will consolidate all NASA wide-area network systems in FY 1997, providing integrated services for operational and administrative communication needs at reduced costs.

Efforts are ongoing to consolidate and streamline major support contract services in order to optimize space operations. In FY 1996, a voluntary contractor partnership was established between the major incumbents, AlliedSignal Technical Services Corporation and Computer Sciences Corporation. Transition to a Consolidated Space Operations Contract (CSOC) is planned. The CSOC acquisition process will be implemented in two phases. In FY 1997, multiple short-term, fixed-price study contracts to develop an Integrated Operations Architecture (IOA) are planned. In FY 1998, a single Cost-Plus-Award-Fee, ten year contract is envisioned to implement the IOA. A full and open competition is planned to develop an integrated architecture and implementation across all NASA programs to produce efficiencies and economies over the life of the contract.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### SPACE NETWORK

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Space Network Services | 6,800 | 5,100 | 3,700 |
| TDRS Replenishment Spacecraft | 147,200 | 162,100 | 107,000 |
| TDRS Replenishment - Launch Services | 3,200 | 17,900 | 50,500 |
| To | 157,200 | 185,100 | 161,200 |

### 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 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 two fully operational satellites in service (TDRS-4 & 5).two fully functional satellites stored on-orbit (TDRS-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 Australia, to increase data return from the Compton Gamma Ray Observatory (CGRO)and support Shuttle MIR operations. TDRS-1, now in its thirteenth 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 TDFS 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 will provide three TDRS spacecraft under a fixed-price, commercial practices contract. The prime contract was awarded to the Hughes Space and Communications Company

in **1995.** and development is now under way. The first spacecraft's launch readiness is scheduled for the third quarter of CY **1999.** 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 AlliedSignal Technical Services Corporation and the Computer Sciences Corporation are the primary support service contractors responsible for maintenance and operations of the ground terminal facilities and orbital operations of the spacecraft as well as engineering and test support. The two contractors established a voluntary partnership in **1996** for these services under the Consolidated Network and Mission Operations (CNMOS)performance-based contract.

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 50 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** !light 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 **1998** budget request.

Space Network services provide the primary communications for orbital operations of the Space Transportation System and its attached payloads. Services are also provided to automated Earth-orbital missions which have communications systems compatible with the TDRS, and can provide nearly continuous high-data-rate services. The Space Network will provide communications services for the International Space Station (ISS), beginning in FY **1998.** 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.

## MEASURES OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | Plan | Actual | plan | Current | plan |
| Number of hours of network service | 26,200 | 26,200 | 26,400 | 27,000 | 35,000 |

The projected output of network services will remain relatively level until FY 1998. The initiation of ISS assembly, and the launch of Earth Observation System (EOS) AM-1 and Landsat-7 will necessitate an increased level of communications services.

### TDRS Replenishment Spacecraft

| | |
|---|---|
| Contract Award<br>Plan: February 1995<br>Actual: February 1995 | Early design activities began in April 1995. The contract was awarded on schedule, but initiation of activity was delayed due to a protest, which was resolved by GAO in July 1995. |
| Preliminary Design Review<br>Plan: July 1996<br>Actual: July 1996 | The review verified that the proposed contractor design will meet NASA performance requirements. |
| Critical Design Review (CDR)<br>Plan: January 1997<br>Revised: April 1997 | Verification that the contractor is prepared to develop, including manufacture, assembly, integrate, and test, the TDRS spacecraft. CDR was re-phased due to the delay in the development of engineering models as a result of the lack of contractor resources and late requirements flow down. The schedule was re-planned with no impact to the completion of integration and test. |
| Start TDRS-H Integration and Test<br>Plan: May 1997<br>Revised: August 1997 | Start of spacecraft assembly, as well as electrical, environmental, and performance testing. The process begins with spacecraft and with spacecraft-level assembly and test. I&T was re-phased due to the delay in the development of engineering models as a result of the lack of contractor resources and late requirements flow down. The schedule was re-planned with no impact to the completion of integration and test. |
| Complete TDRS-H Integration and Test<br>Plan: January 1999 | Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch. |
| Launch TDRS-H<br>Plan: 3rd Qtr FY 1999 | Launch within four 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 scheduled for 2002 and 2003 following the launch of the first TDRS Replenishment Spacecraft. |

## ACCOMPLISHMENTS AND PLANS

In FY 1996, the TDRS Replacement Spacecraft (TDRS-7) was placed in on-orbit storage. Launch services for the TDRS-H Replenishment Spacecraft were negotiated with Lockheed Martin Corporation in May 1996. During July 1996, the preliminary design review for the development of the TDRS Replenishment Spacecraft was completed. Both the TDRS Replacement Spacecraft and the Second TDRSS Ground Terminal programs were completed within the total funding limitations established in response to the FY 1992 Appropriations Conference Report. Space Network extended service (on a reimbursable basis) to the expendable launch vehicle community concluding agreements with U.S.A.F. Titan and Lockheed Martin's commercial Atlas programs. In addition, the Space Network provided data relay services to eight Space Shuttle flights and their attached payloads.

In FY 1997, the Space Network is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. These missions include seven planned Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit such as HST and the CGRO, as well as other compatible missions such as Ocean Topography Experiment, Extreme Ultraviolet Explorer (EUVE), Tropical Rainfall Measurement Mission (TRMM), Department of Defense customers, the X-ray Timing Explorer (XTE), the Starlink research aircraft, and the Long Duration Balloon program.

Development activities will continue with the critical design review of the TDRS Replenishment Spacecraft scheduled for April 1997. TDRS-H integration and test will begin in late August 1997. Negotiations for the TDRS-I and TDRS-J launch services will be definitized in early 1997. The Guam Remote Ground Terminal (GRGT) development will continue with site development at a U.S. Navy location in Guam. The GRGT extends the capability of the White Sands Ground Terminals to provide full service coverage in the former Zone of Exclusion. Within the FY 1995 funds for the Space Network, funding availability of $9.0 million was identified for this activity as a result of completion of the Tracking and Data Relay Satellite (TDRS)-7 and the Second TDRS Ground Terminal projects. The remaining $12.4 million required for this activity are available within the Space Network program funds as a result of receiving reimbursable funds greater than originally anticipated, including revenues resulting from the agreement with Columbia Communications Corporation for lease of excess C-band capacity.

In FY 1998, the Space Network will continue to operate 24 hours per day, 7 days per week providing services to seven Space Shuttle flights and their attached payloads, as well as the International Space Station, Landsat-7, and the Earth Observation System AM-1 mission. Support to the missions listed above will also continue. The Guam Remote Ground Terminal will conclude integration and test activities and become operational late in the fiscal year. Full services will then be available on a continuous basis with no geographical gaps for low-orbit missions. The Replenishment Spacecraft will continue integration and test activities to prepare for the completion of TDRS-H development in early 1999.

## BASIS OF FY 1998 FUNDING REQUIREMENT

### TELECOMMUNICATIONS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Telecommunications ..... | 98,200 | 92,600 | 84,500 |

### PROGRAM GOALS

The Telecommunications 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 Telecommunications 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 Telecommunications program supports NASA's programs in collaborative interagency, international, and commercial enterprises. Many collaborative arrangements are performed on a reimbursable basis.

### STRATEGY FOR ACHIEVING GOALS

NASA's Telecommunications program 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 NASA's telecommunications 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. NASA's telecommunications program 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 telecommunications network.

NASA telecommunications services are provided by the NASA Integrated Services Network (NISN) Project Office, and managed by the Marshall Space Flight Center, in partnership with the Goddard Space Flight Center. NISN is a new organization which

consolidates the NASA Communications and the Program Support Communications Network. 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. This reimbursable revenue is anticipated to continue and has been taken into account in formulating the NASA FY 1998 budget request.

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 supports 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.

NASA's Telecommunications program 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 Telecommunications program.

Initially, the telecommunications services required by NASA were not available commercially. However, with the advancements of telecommunications technology and standards, NASA telecommunications services are now more readily available from commercial sources. NASA will analyze current telecommunications requirements to determine the feasibility of providing these services through commercial sources. Based on the Asynchronous Transfer Mode (ATM) study and cost analyses conducted in FY 1996, NASA has determined that ATM is a viable and cost effective method to support NASA's growing telecommunications needs, and that the technology is available commercially. Similar services provided by legacy systems and networks are also being studied for consolidation.

## MEASU OF PERFORMANCE

| | FY 1996 | | FY 1997 | | FY 1998 |
|---|---|---|---|---|---|
| | plan | Actual | plan | | plan |
| Number of end-user spacecraft contacts | 96,000 | 89,400 | 105,600 | 105,000 | 115,000 |
| Number of locations connected | 430 | 430 | 470 | 400 | 450 |
| Number of electronic conferences | 27,600 | 30,800 | 31,400 | 31,500 | 34,500 |

The decrease in end-user spacecraft contacts in FY 1996 was caused by delays in the launch manifest and reduced support to Hubble Space Telescope. Constrained travel budgets resulted in an increase in the number of electronic conferences. The planned, actual and current number of electronic conferences are currently stated as annual numbers. The budget estimates submitted in the FY 1997 Congressional Budget Estimate displayed the number of electronic conferences based on average monthly occurrences versus annual numbers.

## ACCOMPLISHMENTS AND PLANS

In FY 1996, telecommunications services and systems were provided to support all NASA operational flight systems. Services were also provided for all administrative, programmatic, and technical information exchanges required for pre-flight systems and for NASA transmission of data to NASA-supported scientists and researchers. NISN services were added to support new missions and increased requirements of ongoing missions. The missions include International Solar Terrestrial Physics (ISTP)/Polar, international RADARSAT, Near Earth Asteroid Rendezvous (NEAR), Mars Global Surveyor (MGS), United States Microgravity Laboratory, and International Microgravity Laboratory. In addition. NISN services were extended to new university and contractor locations in support of the scientific missions. The network backbone capacity was also increased for the aeronautics supercomputer program and the International Space Station development. NASA has consolidated multiple telecommunications contracts into one. This allows for improved focus to better manage telecommunications services being provided to NASA.

In FY 1997, NASA will finalize planning and implementation activities for the commercialization of appropriate telecommunication services. These services will transition to commercially available technology required to support increased program requirements, particularly from the Earth Observation System and the International Space Station. NASA will be adding services in support of Mars Global Surveyor, Mars Pathfinder, ISS Phase II, National Oceanic and Atmospheric Administration (NOAA)-K, Advanced Composition Explorer (ACE), Advanced Earth Observing Satellite (ADEOS) and TRMM. From FY 1997 and into FY 1998, growth can be anticipated in the areas of Space Station on-orbit fabrication and Mission To Planet Earth endeavors.

FY 1998 support will continue for Mars Global Surveyor and Pathfinder. Other new service will support Advanced X-Ray Astrophysics Facil ity (AXAF), Cassini, EOS AM-1, Landsat-7, NOAA-L, and Transition Region and Coronal Explorer (TRACE),

Research and
Program
Management

# MISSION SUPPORT

## FY 1998 ESTIMATES

## RESEARCH AND PROGRAM MANAGEMENT

### PROGRAM GOALS

To acquire and maintain a civil service workforce and infrastructure which reflects the cultural diversity of the Nation, which is properly sized and which possesses the right set of human resource skills in the right locations to accomplish NASA's research, development, and operational missions with innovation, excellence, and efficiency.

### STRATEGY FOR ACHIEVING GOALS

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. By the end of FY 2000, NASA plans to have restructured the size and composition of the workforce to fewer than 18,000 civil servants, nearly a 30 percent reduction from the authorized FY 1992 levels of just over 25,000. 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

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 request. The remaining 2% of the request is required to fund travel necessary to manage NASA and its programs and provide the training and other supporting costs for NASA personnel.

### ACCOMPLISHMENTS AND PLANS

NASA exceeded the FTE target included in the NASA Streamlining plan for FY 1996 and continued to make progress towards specific workforce goals established by the National Performance Review. These goals were met through the implementation of the most restrictive hiring policy in recent years and the results of the buyout conducted in FY 1995. We have continued to reduce the infrastructure at Headquarters through the aggressive redeployment of Headquarters personnel to the field centers. At the field Centers, operational activities are being transferred to commercial operators or to other Federal agencies where feasible. We have begun to use temporary and term appointments, which provide additional employment flexibility. Full-time civilian employment at the end of FY 1996 was about 21,000, a reduction of about 4,000 or 16% since 1993.

The agency also successfully met the goals for FY 1996 established as part of the National Performance Review:

- The supervisory span of control has gone from 1:5 in FY 1993 to 1:9 in FY 1996.
- Targeted administrative staffs have declined more than 18% from FY 1993 levels.
- Headquarters employment has been reduced by more than 700 or 34% from FY 1993.

The NASA workforce target for FY 2000 is fewer than 18,000 FTE. Achieving the remaining reduction of 3,000 civil servants from the FY 1996 level represents a formidable objective. Assuming natural attrition rates, NASA will likely fall short of our goal by 1,700 to 1,900 FTE. In addition, relying exclusively on retirement and a continued hiring freeze to reach the agency goals would result in a workforce skill mix that did not match the program requirements of NASA's Strategic Plan. Further, normal losses do not occur at precisely the right time or in the right proportions and locations to meet program requirements and intermediate year budgetary objectives. NASA has stressed, and will continue to stress, the need to minimize adverse impacts on the workforce. The plan is to aggressively use all ongoing, voluntary approaches to reductions for as long as possible before employing involuntary methods.

Central to this strategy in FY 1997 is implementation of an aggressive buyout plan to (1) achieve at least double the number of losses expected under the normal attrition: (2) reach the FTE targets for FY 1999 in FY 1997 at as many Field Centers as possible: and (3) implementing the organizational structures identified by each Center in their workforce plans as quickly as possible. Each NASA Center has structured their buyout planning based on the results of comprehensive workforce assessments and their Workforce 2000 strategic plans. These plans identify the Center of Excellence and Mission for the Center, its restructuring strategy, and the number and skill mix of positions required for FY 2000. Each Center has focused its plans for the buyout at their site based on consideration of what types of positions would be in excess in the future. The agency approach, as well as a summary by Center, is included in the agency's workforce restructuring plan, which is being submitted to Congress with the FY 1998 Congressional budget request.

The FY 1998 budget estimate of $2,070.3 million for Research and Program Management represents a continuation of the aggressive downsizing NASA has undertaken since FY 1993 and incorporates the reduction associated with the 1997 buyout. The requested funding level for FY 1998 is a decrease of $22.2 million from the FY 1997 budget plan of $2,092.5 million. This request funds 19,559 full-time equivalents (FTEs), a reduction of 942 FTEs from the expected FY 1997 level of 20.500 FTE. Of this total decrease, funding for Personnel and Related Costs is increased $1.8 million: funding for Travel remains unchanged at $45.5 million; and funding for Research and Operations Support is decreased $24 million. Of the increase for Salaries and Expenses: $8 million is for the full year cost of the FY 1997 pay raise: $25 million is for the planned 2.8% payraise in FY 1998: $9 million is due to increased costs of health care and the increased share of government payments for the Federal Employees Retirement System: $17.8 million is due to the costs of "normal" promotions, military detailee increases, employee transfers from Center to Center, increased workers compensation costs, lump sum and secruity investigations. These increases are offset by savings of $58 million associated with the reduction of 942 FTE. In addition, funding for Research Operations Support is reduced $24 million.

In summary, the FY 1998 budget requirement of $2,070,300,000 will provide for 19,559 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.** ComDensation and Benefits

1. ComDensation

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 ComDensation: 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, 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 are 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 Develoument 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 Ouerations 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 Installationwide 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.

## UMMARY OF BUDGET PLAN BY FUNCTION

| | FY 1996 | FY 1997 (Millions of Dollars) | FY 1998 |
|---|---|---|---|
| I. Personnel and related costs | 1,553.5 | 1,611.0 | 1,612.8 |
| II. Travel | 41.6 | 45.5 | 45.5 |
| III. Research operations support | 452.8 | 436.0 | 412.0 |
| **Total** | **2,047.9** | **2,092.5** | **2,070.3** |

## DETAIL OF BUDGET PLAN BY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Millions of Dollars) | |
| **I. Personnel and related costs** | **1,553.5** | **1,611.0** | **1,612.8** |
| A. Compensation and benefits | 1,511.0 | 1,581.9 | 1,586.0 |
| 1. Compensation | 1,261.4 | 1,304.3 | 1,307.0 |
| 2. Benefits | 249.6 | 277.6 | 279.0 |
| B. Supporting costs | **42.5** | **29.1** | **26.8** |
| 1. Transfer of personnel | 2.5 | 3.0 | 1.4 |
| 2. Investigative services | 6.7 | 1.2 | 1.2 |
| 3. Personnel training | 33.3 | 24.9 | 24.2 |
| **II. Travel** | **41.6** | **45.5** | **45.5** |
| A. Program travel | 27.7 | 31.5 | 31.5 |
| B. Scientific and technical development travel | 4.0 | 4.0 | 4.0 |
| C. Management and operations travel | 9.9 | 10.0 | 10.0 |
| **III. Research Operations support** | **452.8** | **436.0** | **412.0** |
| A. Facilities services | 136.1 | 130.5 | 130.7 |
| B. Technical services | 150.7 | 138.5 | 122.8 |
| C. Management and operations | 166.0 | 167.0 | 158.5 |
| Total | **2,047.9** | **2,092.5** | **2,070.3** |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
RESEARCH AND PROGRAM MANAGEMENT - FY 1998 ESTIMATES
DISTRIBUTION OF BUDGET PLAN BY FUNCTION BY INSTALLATION
(MILLIONS OF DOLLARS)

| FUNCTION | TOTAL NASA | JSC | KSC | MSFC | SSC | GSFC | ARC | DFRC | LARC | LERC | HQS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PERSONNEL AND RELATED COSTS** | | | | | | | | | | | |
| FY 1996 | 1,553.5 | 274.0 | 154.7 | 221.6 | 15.0 | 256.8 | 128.5 | 33.0 | 174.6 | 161.6 | 133.7 |
| FY 1997 | 1,611.0 | 285.1 | 157.1 | 232.4 | 19.8 | 277.4 | 131.0 | 40.7 | 179.7 | 165.8 | 122.0 |
| FY 1998 | 1,612.8 | 285.9 | 146.4 | 234.2 | 19.6 | 274.8 | 134.1 | 46.9 | 186.6 | 161.8 | 122.5 |
| FY 1996 | 41.6 | 8.0 | 3.5 | 4.7 | .5 | 6.6 | 3.8 | .8 | 4.2 | 3.3 | 6.2 |
| FY 1997 | 45.5 | 8.5 | 3.7 | 5.8 | .6 | 6.8 | 3.4 | 1.4 | 3.6 | 3.4 | 8.3 |
| | 45.5 | 8.0 | 3.5 | 5.7 | .6 | 6.8 | 3.3 | 1.4 | 3.6 | 3.5 | 9.1 |
| **RESEARCH OPERATIONS SUPPORT** | | | | | | | | | | | |
| FY 1996 | 452.8 | 70.3 | 78.1 | 50.3 | 15.9 | 54.3 | 24.2 | 5.7 | 21.2 | 30.8 | 102.0 |
| FY 1997 | 436.0 | 50.0 | 69.3 | 52.2 | 22.6 | 52.5 | 28.8 | 6.3 | 23.4 | 27.4 | 103.5 |
| FY 1998 | 412.0 | 44.2 | 71.7 | 52.8 | 22.9 | 50.9 | 28.7 | 6.8 | 22.6 | 24.9 | 86.5 |
| **TOTAL** | | | | | | | | | | | |
| FY 1996 | 2,047.9 | 352.3 | 236.3 | 276.6 | 31.4 | 317.7 | 156.5 | 39.5 | 200.0 | 195.7 | 241.9 |
| FY 1997 | 2,092.5 | 343.6 | 230.1 | 290.4 | 43.0 | 336.7 | 163.2 | 48.4 | 206.7 | 196.6 | 233.8 |
| FY 1998 | 2,070.3 | 338.1 | 221.6 | 292.7 | 43.1 | 332.5 | 166.1 | 55.1 | 212.8 | 190.2 | 218.1 |

## SUMMARY OF BUDGET PLAN BY INSTALLATION
(MILLIONS OF DOLLARS)

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Johnson Space Center | 352.3 | 343.6 | 338.1 |
| Kennedy Space Center | 236.3 | 230.1 | 221.6 |
| Marshall Space Flight Center | 276.6 | 290.4 | 292.7 |
| Stennis Space Center | 31.4 | 43.0 | 43.1 |
| Goddard Space Flight Center | 317.7 | 336.7 | 332.5 |
| Ames Research Center | 156.5 | 163.2 | 166.1 |
| Dryden Flight Research Center | 39.5 | 48.4 | 55.1 |
| Langley Research Center | 200.0 | 206.7 | 212.8 |
| Lewis Research Center | 195.7 | 196.6 | 190.2 |
| Headquarters | 241.9 | 233.8 | 218.1 |
| Total | 2,047.9 | 2,092.5 | 2,070.3 |

## DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY INSTALLATION

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Johnson Space Center | 3,335 | 3,294 | 3,065 |
| Kennedy Space Center | 2,145 | 2,036 | 1,824 |
| Marshall Space Flight Center | 3,080 | 2,964 | 2.779 |
| Stennis Space Center | 200 | 237 | 238 |
| Goddard Space Flight Center | 3,479 | 3,495 | 3,472 |
| Ames Research Center | 1,520 | 1,466 | 1,436 |
| Dryden Flight Research Center | 438 | 575 | 616 |
| Langley Research Center | 2,479 | 2,475 | 2,450 |
| Lewis Research Center | 2,220 | 2,170 | 2,022 |
| Headquarters | 1,390 | 1,224 | 1.143 |
| **Subtotal, full-time permanent workyears** | 20.286 | 19,936 | 19,045 |
| Other controlled FTEs | 652 | 565 | 514 |
| **Total, full-time equivalents** | 20.938 | 20.501 | 19.559 |

## DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 1,934 | 2,188 | 2,425 |
| U.S./Russian cooperative program | 63 | 60 | 26 |
| Space shuttle | 2,669 | 2,459 | 2,298 |
| Payload and utilization operations | 1,298 | 1,252 | 701 |
| Space science | 2,330 | 2,227 | 2,146 |
| Life and microgravity sciences | 1,020 | 855 | 791 |
| Mission to planet Earth | 1,531 | 1,679 | 1,660 |
| Aeronautical research and technology | 3,284 | 3,425 | 3,440 |
| Advanced space transportation technology | 934 | 979 | 972 |
| Commercial technology programs | 231 | 205 | 181 |
| Academic programs | 70 | 65 | 62 |
| Mission communication services | 408 | 366 | 358 |
| Space communications services | 133 | 126 | 130 |
| Safety, reliability and quality assurance | 124 | 105 | 105 |
| Construction of facilities | 224 | 176 | 172 |
| **Subtotal, direct full-time permanent FTEs** | **16.253** | **16,167** | **15.467** |
| Program management (Headquarters) | 55 | 55 | 55 |
| Center management and operations | 3.978 | 3,714 | 3,523 |
| **Subtotal, full-time permanent FTEs** | **20,286** | **19,936** | **19.045** |
| Other controlled FTEs | 652 | 565 | 514 |
| **Total. full-time equivalents** | **20,938** | **20,501** | **19,559** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATES**

**LYNDON B. JOHNSON SPACE CENTER**

**ROLES AND MISSIONS**

**SPACE STATION** - Development of the International Space Station will provide an on-orbit, habitable laboratory for science and research activities, including flight and test hardware and software, flight demonstrations for risk mitigation, ground operations capability and facility construction, shuttle hardware and integration for assembly and operation of the station, mission planning, and integration of Space Station systems.

Space Station elements will be provided by the U. S. and our international partners. The U. S. elements include two nodes, a laboratory module, truss segments, four photovoltaic arrays, a habitation module, three pressurized mating adapters, a cupola, unpressurized logistics carriers and a centrifuge accommodation module. 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. elements also include the FGB energy tug, being provided by a Russian firm under the Boeing prime contract, and pressurized logistics modules, provided by Italy.

Canada, the European nations, Japan, and Russia are also developing hardware for the international Space Station program. Laboratory elements will be provided by the Japanese and European Space Agencies. Canada will provide the remote manipulator system, vital for assembly of the station. The Russian Space Agency is providing experiment, power, life support and service modules, Soyuz crew transfer vehicle, and universal docking modules.

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.

**U.S./RUSSIAN COOPERATIVE PROGRAM** - JSC will continue to conduct management of the U.S./Russian Cooperative Program.

**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 also provides support to Spacelab, the engineering and technical base, payload operations and support equipment, and advanced programs.

**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** - The Center 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. It will 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. These activities are being consolidated into a biomedical science institute. The Center will integrate life science flight experiments for Spacelab: operate integrated payload systems: and train mission and payload specialists in the science aspect of their missions. In addition, the JSC will provide mission integration and operations functions for experiments flown on the NASA-Mir program, including Space Shuttle flights as well as those transported via Russian launch vehicle applications.

**CENTER MANAGEMENT** AND **OPERATIONS** - Provides management, administrative, and financial oversight of NASA programmatic elements under JSC cognizance. In addition, provides for the operation and maintenance of the institutional facilities, systems, and equipment.

## DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## JOHNSONSPACECENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 965 | 1,026 | 1,287 |
| U.S./Russian cooperative program | 58 | 56 | 23 |
| Space shuttle | 1,081 | 1,064 | 1,060 |
| Payload and utilization operations | 584 | 545 | 175 |
| Space science | 39 | 40 | 37 |
| Life and microgravity sciences | 62 | 50 | 69 |
| Mission to planet Earth | 0 | 0 | 0 |
| Aeronautical research and technology | 0 | 0 | 0 |
| Advanced space transportation technology | 13 | 9 | 5 |
| Commercial technology programs | 23 | 26 | 20 |
| Academic programs | 8 | 6 | 6 |
| Mission communication services | 7 | 22 | 20 |
| Space communications services | 0 | 4 | 6 |
| Safety, reliability and quality assurance | 4 | 1 | 2 |
| Construction of facilities | 25 | 23 | 22 |
| **Subtotal, direct full-time permanent FTEs** | **2,869** | **2.872** | **2,732** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 466 | 422 | 333 |
| **Subtotal, full-time permanent FTEs** | **3,335** | **3,294** | **3,065** |
| Other controlled FTEs | 97 | 98 | 98 |
| **Total, full-time equivalents** | **3.432** | **3.392** | **3.163** |

## RESEARCH AND PROGRAM MANAGEMENT

## FISCAL YEAR 1998 ESTIMATES

## JOHN F. KENNEDY SPACE CENTER

## ROLES AND MISSIONS

**SPACE STATION** - The Kennedy Space Center (KSC) shares responsibility for operations capability and construction with the Johnson Space Center (JSC) to develop a set of facilities, systems, and capabilities to conduct the operations of the Space Station. KSC will develop launch site operations capabilities for conducting prelaunch and post-landing ground operations including integrated testing, interface verification, servicing, launch activities, and experiment-to rack physical integration. KSC will serve as the primary agent for management and integration of ground processes for all U.S. launched International Space Station elements from manufacture and assembly through verification and launch.

**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 AND UTILIZATION OPERATIONS** - KSC serves as the Lead Center for all payload requirements at **NASA.** KSC will provide support for Spacelab assembly and checkout, payload experiment integration, upper stages processing, Spacelab and ground support equipment (GSE) logistics and operations and maintenance of GSE.

**EXPENDABLE LAUNCH VEHICLES** - KSC will provide government 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 provide for the operation and maintenance of the institutional facilities, systems, and equipment.

## DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## SPACE CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 198 | 279 | 304 |
| U.S. /Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 923 | 796 | 709 |
| Payload and utilization operations | 392 | 392 | 259 |
| Space science | 54 | 53 | 30 |
| Life and microgravity sciences | 91 | 100 | 92 |
| Mission to planet Earth | 6 | 6 | 25 |
| Aeronautical research and technology | 0 | 0 | 0 |
| Advanced space transportation technology | 11 | 14 | 11 |
| Commercial technology programs | 15 | 11 | 11 |
| Academic programs | 1 | 2 | 2 |
| Mission communication services | 0 | 0 | 0 |
| Space communications services | 0 | 0 | 0 |
| Safety, reliability and quality assurance | 7 | 7 | 5 |
| Construction of facilities | 43 | 38 | 38 |
| **Subtotal, direct full-time permanent FTEs** | 1.741 | 1,698 | 1,486 |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 404 | 338 | 338 |
| **Subtotal, full-time permanent FTEs** | 2,145 | 2.036 | 1.824 |
| Other controlled FTEs | 75 | 99 | 97 |
| **Total, full-time equivalents** | 2.220 | 2.135 | 1.921 |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATES**

**GEORGE C. MARSHALL SPACE IGH CENTER**

**ROLES AND MISSIONS**

**SPACE STATION** - The Center will provide engineering support to the program including engineering analysis in support of the station system engineering and integration effort and the work of the prime and major subcontractors. Included also are the logistics camers development and maintenance activities and the design integration of cargo elements for Station mission build and logistics supply flights. It will be responsible for developing payload utilization capabilities and planning and executing payload integration and operations activities. This includes the development and operation of the EXPRESS Rack and Pallet payload camers, the payload operations integration center, and data systems.

**SPACE SHUTTLE** - As the Center of Excellence for establishing, upgrading, and maintaining world class excellence in space propulsion programs, MSFC will provide for the design, development, and procurement of propulsion elements for the space shuttle transportation system.

**SPACE SCIENCE** - MSFC will lead the development and operations of the Advanced X-ray Astrophysics Facility (AXAF) and the Relativity Mission (Gravity Probe-B) as well as management of selected payloads. As the Center of Excellence for Space Optics, MSFC will provide design and development effort.

**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, improve the quality of life on Earth, and strengthen the foundations for continuing the exploration and development of space. Furthermore, emphasis will be given to developing and transitioning to the private sector the technology and applications of products developed for space.

**AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY** - The Center will provide propulsion and vehicle technology to reduce cost and schedule risk in the development of next generation space transportation vehicles. It will develop technology in hybrid, liquid, other energy source propulsion systems, advanced manufacturing processes, and vehicle 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.

**MISSION TO PLANET EARTH** - 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 also lead in the establishment and operation of the Global Hydrology and Climate Center

**MISSION/SPACE COMMUNICATION SERVICES** - Manage and maintain 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** - Provide 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 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 523 | 602 | 589 |
| U.S./Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 566 | 501 | 422 |
| Payload and utilization operations | 189 | 153 | 138 |
| Space science | 445 | 358 | 288 |
| Life and microgravity sciences | 256 | 231 | 228 |
| Mission to planet Earth | 61 | 50 | 48 |
| Aeronautical research and technology | 0 | 0 | 0 |
| Advanced space transportation technology | 579 | 591 | 616 |
| Commercial technology programs | 101 | 75 | 59 |
| Academic programs | 8 | 9 | 9 |
| Mission communication services | 0 | 1 | 1 |
| Space communications services | 14 | 16 | 17 |
| Safety, reliability and quality assurance | 2 | 1 | 1 |
| Construction of facilities | 24 | 24 | 23 |
| **Subtotal, direct full-time permanent FTEs** | **2.768** | **2,612** | **2,439** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 312 | 352 | 340 |
| **Subtotal, full-time permanent FTEs** | **3,080** | **2,964** | **2,779** |
| Other controlled FTEs | 46 | 45 | 40 |
| **Total. full-time equivalents** | **3.126** | **3.009** | **2.819** |

## RESEARCH AND PROGRAM MANAGEMENT

## FISCAL YEAR 1998 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 center and related capabilities 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. This support the Center's capability to conduct advanced propulsion test technology research and development for government and commercial propulsion programs.

**MISSION TO PLANET EARTH** - Through the Commercial Remote Sensing Program, SSC will enhance U.S. economic competitiveness via commercial partnership programs which 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 increase our understanding of environmental systems sciences, with emphasis on coastal research of both land and oceans.

**AERONAUTICS AND SPACE TRANSPORTATION 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 which supports the agency goal of reducing the cost of access to space.

**CENTER MANAGEMENT AND OPERATIONS** - The Center will provide, operate, maintain, and manage the institutional base and laboratories required to accomplish and support assigned programs of NASA 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 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 0 | 0 | 0 |
| U.S./Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 39 | 39 | 56 |
| Payload and utilization operations | 25 | 25 | 8 |
| Space science | 0 | 0 | 0 |
| Life and microgravity sciences | 0 | 0 | 0 |
| Mission to planet Earth | 20 | 20 | 20 |
| Aeronautical research and technology | 0 | 0 | 0 |
| Advanced space transportation technology | 18 | 50 | 50 |
| Commercial technology programs | 3 | 4 | 4 |
| Academic programs | 4 | 4 | 4 |
| Mission communication services | 0 | 0 | 0 |
| Space communications services | 0 | 0 | 0 |
| Safety, reliability and quality assurance | 1 | 1 | 1 |
| Construction of facilities | 11 | 11 | 11 |
| **Subtotal, direct full-time permanent FTEs** | **121** | **154** | **154** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 79 | 83 | 84 |
| **Subtotal, full-time permanent FTEs** | **200** | **237** | **238** |
| Other controlled FTEs | 15 | 16 | 9 |
| **Total. full-time equivalents** | **215** | **253** | **247** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 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.

**EXPENDABLE LAUNCH VEHICLES** - Technical oversight for NASA payloads of the small and medium class ELVs, such as Pegasus and Delta, used to put a wide variety of spacecraft into a broad spectrum of orbits.

**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 space born instruments, and on-board spacecraft systems and subsystems.

**MISSION TO PLANET EARTH** - Lead Center for MTPE, 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.

**AERONAUTICS *AND* SPACE TRANSPORTATION TECHNOLOGY** - The Wallops Flight Facility conducts 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 and space science 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 FULLTIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## GODDARD SPACE FLIGHT CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 0 | 0 | 0 |
| U.S./Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 6 | 7 | 7 |
| Payload and utilization operations | 35 | 39 | 39 |
| Space science | 1,255 | 1,278 | 1,314 |
| Life and microgravity sciences | 30 | 0 | 0 |
| Mission to planet Earth | 1.011 | 1,090 | 1,045 |
| Aeronautical research and technology | 27 | 28 | 26 |
| Advanced space transportation technology | 0 | 0 | 0 |
| Commericial technology programs | 15 | 11 | 12 |
| Academic programs | 2 | 3 | 3 |
| Mission communication services | 335 | 298 | 296 |
| Space communications services | 107 | 95 | 89 |
| Safety, reliability and quality assurance | 14 | 7 | 7 |
| Construction of facilities | 53 | 47 | 45 |
| **Subtotal. direct full-time permanent FTEs** | **2.890** | **2,903** | **2,883** |
| Program management (Headquarters) | **0** | **0** | **0** |
| Center management and operations | 589 | 592 | 589 |
| **Subtotal, full-time permanent FTEs** | **3,479** | **3,495** | **3.472** |
| Other controlled FTEs | 84 | 78 | 70 |
| **Total, full-time equivalents** | **3.563** | **3.573** | **3.542** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATES**

AMES **RESEARCH CENTER**

**ROLES AND MISSIONS**

**SPACE SCIENCE** - Ames has the agency lead role in Astrobiology (the study of life in the universe) which in Space Science 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 (R&D) in advanced information technologies are directed toward significantly increasing the efficiency of SOFIA as it becomes operational. Development of the Lunar Prospector continues as does advanced studies of future Mars missions, with emphasis on telepresence and telescience technologies to enhance robotics science productivity.

**LIFE AND MICROGRAVITY SCIENCES** - Ames has the agency lead role in Astrobiology and Gravitational Biology, 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 the how gravity affects the development, structure and functions of living systems. 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.

**MISSION TO PLANET EARTH** - Ames has the agency lead role in Astrobiology which in Earth Science focuses on the relationship between life on Earth and our changing environment. 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.

**AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY** - Conduct aeronautics research in ground-based and airborne automation technologies, human factors and operational methodologies for efficient, safe and effective airspace 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 to improve efficiency, affordability, and performance. Continue an interdisciplinary research program which provides the technology base for the development of subsonic and high speed transport aircraft. Emphasize joint research and technology projects with other NASA installations, government agencies, industry and academia.

Strengthen basic research and technology development for aerospace systems that transport humans and instrumentation to and from space and within the atmospheres of other bodies within the solar system. Research is conducted on thermal protection systems and arcjet testing is performed to meet national needs for access to space and planetary exploration.

**SAFETY, RELIABILITY AND QUALITY ASSURANCE** - Provide institutional safety and health programs and develop and integrate Safety, Reliability and Quality Assurance guidelines into program and project development.

**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.

## DISTRIBUTION OF FULLTIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## AMES RESEARCH CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 38 | 43 | 52 |
| U.S. /Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 0 | 0 | 0 |
| Payload and utilization operations | 0 | 0 | 0 |
| Space science | 115 | 115 | 113 |
| Life and microgravity sciences | 115 | 106 | 79 |
| Mission to planet Earth | 132 | 101 | 124 |
| Aeronautical research and technology | 662 | 663 | 662 |
| Advanced space transportation technology | 71 | 73 | 69 |
| Commericial technology programs | 11 | 12 | 14 |
| Academic programs | 0 | 0 | 0 |
| Mission communication services | 11 | 0 | 0 |
| Space communications services | 0 | 0 | 0 |
| Safety, reliability and quality assurance | 15 | 15 | 16 |
| Construction of facilities | 8 | 8 | 8 |
| **Subtotal, direct full-time permanent FTEs** | **1,178** | **1,136** | **1,137** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 342 | 330 | 299 |
| **Subtotal, full-time permanent FTEs** | **1,520** | **1,466** | **1,436** |
| Other controlled FTEs | 75 | 77 | 54 |
| **Total, full-time equivalents** | **1,595** | **1,543** | **1,490** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATES**

**DRYDEN FLIGHT RESEARCH CENTER**

**CENTER ROLES AND MISSIONS**

**AERONAUTICS AND SPACE TRANSPORTATION 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.

**SHUTTLE PROGRAMS/PAYLOAD AND UTILIZATION OPERATIONS** - The DFRC will 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.

**CENTER MANAGEMENT** AND **OPERATIONS** - Provide administrative services in support of Center management and provides for the operation and maintenance **of** the Institutional facilities, systems and equipment.

## DISTRIBUTION OF FULLTIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## DRYDEN FLIGHT RCH CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 0 | 0 | 0 |
| U.S. /Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 15 | 19 | 19 |
| Payload and utilization operations | 0 | 0 | 0 |
| Space science | 0 | 0 | 0 |
| Life and microgravity sciences | 0 | 0 | 0 |
| Mission to planet Earth | 0 | 42 | 42 |
| Aeronautical research and technology | 219 | 274 | 318 |
| Advanced space transportation technology | 55 | 90 | 80 |
| Commericial technology programs | 2 | 3 | 3 |
| Academic programs | 0 | 0 | 0 |
| Mission communication services | 19 | 19 | 19 |
| Space communications services | 0 | 0 | 0 |
| Safety, reliability and quality assurance | 12 | 12 | 12 |
| Construction of facilities | 0 | 0 | 0 |
| **Subtotal, direct full-time permanent FTEs** | **322** | **459** | **493** |
| Program management (Headquarters) | **0** | **0** | **0** |
| Center management and operations | 116 | 116 | 123 |
| **Subtotal, full-time permanent FTEs** | **430** | **575** | **616** |
| Other controlled FTEs | 21 | 17 | 15 |
| **Total, full-time equivalents** | **459** | **592** | **631** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATE**

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**ROLES AND MISSIONS**

**AERONAUTICS AND SPACE TRANSPORTATION 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.

Develop innovative new airframe systems to improve safety and significantly reduce cost per seat mile of commericial transport aircraft and reduce emissions to improve environmental compatibility. Pioneer the development of new materials, structural concepts, and fabricate technologies to revolutionize the cost, performance, and safety of future aircraft structures for radically new aircraft design.

Study critical environmental compatibility issues in order to make decisions on future high speed civil transport technology and development programs. Develop technology options for realization of practical hypersonic and transatmospheric flight.

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.

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.

**MISSION TO PLANET EARTH** - Perform an agency-designated Atmospheric Science mission role in support of the Mission to Planet Earth Enterpise in the NASA Strategic Plan. 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: explore advanced laser and LIDAR technologies for Earth science missions: 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. 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 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 criteria for high quality science return within cost and schedule constrains are met: 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 space science instruments and systems. Langley is developing the Phase B definition of 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.

**LIFE *AND* MICROGRAVITY SCIENCES** - Conduct space radiation exposure studies to support of current and future human space efforts for a more accurate assessment of astronaut radiation exposures and body shielding factors: performs system engineering studies and analysis in support of the microgravity flight experiments program: and provides education and public outreach materials for microgravity sciences and applications.

**SYSTEMS ANALYSIS/INDEPENDENT PROGRAM EVALUATION** AND **ASSESSMENT** - Serve as the Agency lead center for systems analysis an the conduct of independent evaluation and assessment 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. Support the Administrator's Program Management Council (PMC)in the organization, administration, and technical support of PMC review process.

**SAFETY. RELIABILITY. AND QUALITY ASSURANCE** - Provide a Safety, Reliability, and Quality Assurance program that conducts independent assessment activities which reduce program risk.

**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 FULLTIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## LANGLEY RESEARCH CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 24 | 30 | 29 |
| U.S./Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 0 | 0 | 0 |
| Payload and utilization operations | 1 | 29 | 28 |
| Space science | 104 | 81 | 80 |
| Life and microgravity sciences | 78 | 29 | 29 |
| Mission to planet Earth | 193 | 266 | 265 |
| Aeronautical research and technology | 1,361 | 1,426 | 1,422 |
| Advanced space transportation technology | 136 | 122 | 119 |
| Commericial technology programs | 32 | 33 | 33 |
| Academic programs | 0 | 0 | 0 |
| Mission communication services | 0 | 0 | 0 |
| Space communications services | 0 | 0 | 0 |
| Safety, reliability and quality assurance | 3 | 2 | 2 |
| Construction of facilities | 39 | 4 | 4 |
| **Subtotal, direct full-time permanent FTEs** | **1,971** | **2,022** | **2,011** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 508 | 453 | 439 |
| **Subtotal, full-time permanent FTEs** | **2.479** | **2,475** | **2,450** |
| Other controlled FTEs | 106 | 50 | 50 |
| **Total, full-time equivalents** | **2.585** | **2.525** | **2.500** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 ESTIMATES**

**LEWIS RESEARCH CENTER**

**ROLES AND MISSIONS**

**LIFE AND MICROGRAVITY SCIENCES** - The Lewis Research Center (LeRC) provides leadership and management of the fluid physics, combustion science, acceleration measurement and telescience disciplines of NASA's Microgravity Science Program. Conducts and sponsors ground-based scientific studies that may lead to experiments in space. Lewis has a substantial effort in the design, buildup, testing, and integration of hardware for experiment packages to be launched aboard the Space Shuttle and the utilization of the Space Station for scientific missions.

**SPACE STATION** - LeRC 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** - LeRC manages and operates "next generation technology" communications satellite to prove high risk communication technologies, to transfer the knowledge gained to US satellite industry developers and users, and to reaffirm the US satellite communications preeminence in this rapidly growing world-wide market. The Center also ensures timely and high quality availability of radio frequency spectrum to enable the realization of NASA goals; actively stimulating the effective use of the Advanced Communications Technology Satellite (ACTS).

**AERONAUTICAL RESEARCH AND TECHNOLOGY** - As the NASA Lead Center for Aeropropulsion, LeRC conducts world-class research critical to the Agency Aeronautics Enterprise goals of developing and transferring enabling technologies to U.S. industry and other government agencies. The Center's Aeropropulsion program is 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, and high performance aircraft propulsion systems through innovative application of research in materials, structures, internal fluid mechanics, instrumentation and controls, interdisciplinary technologies, and aircraft icing.

As the NASA Center of Excellence in Turbomachinery, LeRC's expertise is critical to advancing the Agency's goals in the aeronautics and space programs. This designation enables LeRC to be a cost effective resource across multiple Agency programs in the vital and strategic discipline area of turbomachinery. 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.

**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
## LEWIS RESEARCH CENTER

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 158 | 181 | 151 |
| U.S. /Russian cooperative program | 0 | 0 | 0 |
| Space shuttle | 0 | 0 | 0 |
| Payload and utilization operations | 35 | 41 | 41 |
| Space science | 236 | 227 | 215 |
| Life and microgravity sciences | 308 | 273 | 234 |
| Mission to planet Earth | 38 | 40 | 31 |
| Aeronautical research and technology | 960 | 986 | 970 |
| Advanced space transportation technology | 51 | 30 | 22 |
| Commericial technology programs | 11 | 18 | 18 |
| Academic programs | 14 | 11 | 11 |
| Mission communication services | 3 | 6 | 8 |
| Space communications services | 8 | 7 | 14 |
| Safety, reliability and quality assurance | 12 | 5 | 5 |
| Construction of facilities | 0 | 0 | 0 |
| **Subtotal, direct full-time permanent FTEs** | **1.834** | **1,825** | **1,720** |
| Program management (Headquarters) | 0 | 0 | 0 |
| Center management and operations | 386 | 345 | 302 |
| **Subtotal, full-time permanent FTEs** | **2,220** | **2,170** | **2,022** |
| Other controlled FTEs | 57 | 61 | 67 |
| **Total, full-time equivalents** | **2.277** | **2.231** | **2.089** |

**RESEARCH AND PROGRAM MANAGEMENT**

**FISCAL YEAR 1998 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, Mission to Planet Earth, Aeronautics, 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, 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.

The Office of Headquarters Operations provides and manages the infrastructure necessary to support the Headquarters installation.

**PROGRAM MANAGEMENT** - A cadre of personnel presently assigned to Headquarters provides program management for the NASA Management Office at Jet Propulsion Lab, communications stations in Spain and Australia, international representatives in France , Japan, and Moscow, and Intergovernmental Personnel Assignments/Detailees at various governmental, educational, and commercial organizations. This new function was created to reflect the operational components that logically report directly to Headquarters due to their function but who are not located on-site.

## DISTRIBUTION OF FULLTIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
## NASA HEADQUARTERS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Space station | 28 | 27 | 13 |
| U.S./Russian cooperative program | 5 | 4 | 3 |
| Space shuttle | 39 | 33 | 25 |
| Payload and utilization operations | 37 | 28 | 13 |
| Space science | 82 | 75 | 69 |
| Life and microgravity sciences | 80 | 66 | 60 |
| Mission to planet Earth | 70 | 64 | 60 |
| Aeronautical research and technology | 55 | 48 | 42 |
| Advanced space transportation technology | 0 | 0 | 0 |
| Commericial technology programs | 18 | 12 | 7 |
| Academic programs | 33 | 30 | 27 |
| Mission communication services | 33 | 20 | 14 |
| Space communications services | 4 | 4 | 4 |
| Safety, reliability and quality assurance | 54 | 54 | 54 |
| Construction of facilities | 21 | 21 | 21 |
| **Subtotal, direct full-time permanent FTEs** | **559** | **486** | **412** |
| Program management (Headquarters) | 55 | 55 | 55 |
| Center management and operations | 776 | 683 | 676 |
| **Subtotal, full-time permanent FTEs** | **1,390** | **1,224** | **1,143** |
| Other controlled FTEs | 76 | 24 | 14 |
| **Total, full-time equivalents** | **1,466** | **1,248** | **1,157** |

## DETAIL OF PERMANENT POSITIONS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Executive level II | 1 | 1 | 1 |
| Executive level IV | 2 | 2 | 2 |
| **Subtotal** | **3** | **3** | **3** |
| ES-6 | 57 | 54 | 53 |
| ES-5 | 95 | 90 | 88 |
| ES-4 | 239 | 227 | 220 |
| ES-3 | 44 | 42 | 41 |
| ES-2 | 45 | 43 | 41 |
| ES-1 | 56 | 53 | 52 |
| **Subtotal** | **536** | **509** | **495** |
| CA | 1 | 1 | 1 |
| SL/ST | 64 | 85 | 85 |
| GS/GM-15 | 2,375 | 2.303 | 2,233 |
| GS/GM-14 | 3,498 | 3,392 | 3,288 |
| GS/GM-13 | 6,604 | 6,404 | 6.208 |
| GS-12 | 2,408 | 2,335 | 2,264 |
| GS-11 | 1,395 | 1,353 | 1,311 |
| GS-10 | 313 | 304 | 294 |
| GS-09 | 593 | 575 | 557 |
| GS-08 | 273 | 265 | 257 |
| GS-07 | 726 | 704 | 682 |
| GS-06 | 687 | 666 | 646 |
| GS-05 | 288 | 279 | 271 |
| GS-04 | 47 | 46 | 44 |
| GS-03 | 4 | 4 | 4 |
| GS-02 | 2 | 2 | 2 |
| **Subtotal** | **19.278** | **18,718** | **18,147** |
| Special ungraded positions established by NASA Administrator | 27 | 26 | 25 |
| Ungraded positions | 434 | 421 | 408 |
| **Total permanent positions** | **20.278** | **19.677** | **19.078** |
| Unfilled positions, EOY | *0* | *0* | *0* |
| **Total, permanent employment, EOY** | **20.278** | **19.677** | **19.078** |

## PERSONNEL SUMMARY

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| **Average GS/GM grade** | 12.1 | 12.1 | 12.1 |
| **Average ES salary** | $114,264 | $118,035 | $121,340 |
| **Average GS/GM salary** | $59,910 | $62,306 | $64,487 |
| **Average salary of special ungraded positions established by NASA Administrator** | $91,460 | $94,478 | $97,124 |
| **Average salary of ungraded positions** | $41,570 | $42,942 | $44,144 |

## :EN :A AND CA INVESTMENT

**JOHNSON SPACE CENTER** - The Lyndon B. Johnson Space Center is located 20 miles southeast of Houston, Texas. NASA owns 1,618 acres of land at the Houston site and uses another 60,552 at the White Sands Test Facility, Las Cruces, New Mexico. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,568,023,000 as of September 30, 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $2,381,369,000 as of September 30. 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $2,796,658,000 as of September 30. 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $535,234,000 as of September 30, 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $2,288,392,000 as of September 30, 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $1,231,604,000 as of September 30, 1996.

**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 replacement cost at Dryden, including fixed assets in progress and contractor-held facilities at various locations, as of September 30, 1996 was $369,923,000.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,154,697,000 as of September 30, 1996.

**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 replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $894,819,000 as September 30, 1996.

**NASA HEADQUARTERS** - NASA Headquarters is located at Two Independence Square, 300 E St. SW, Washington, D.C.

**Construction of Facilities**

## MSSION SUPPORT

## FISCAL YEAR 1998 ESTIMATES

## BUDGET SUMMARY

**CONSTRUCTION OF FACILITIES**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| | | (Thousands of Dollars) | | |
| Human Space Flight Appropriation | 35,500 | 8,200 | 6,800 | MS 4-10 |
| Science, Aeronautics and Technology Appropriation | 27,500 | 2,300 | 5,700 | MS 4-21 |
| *Mission Support Appropriation | 144,940 | 155,300 | 159,400 | MS 4-30 |
| Total | 207,940 | 165,900 | 171,900 | |

*see page 4-30 for center distribution

Summary
Information

**MISSION SUPPORT**
**CONSTRUCTION OF FACILITIES**
**FISCAL YEAR 1998 BUDGET ESTIMATES**

## PROGRAM GOALS

The goal of the Construction of Facilities program is to provide the facilities that are critical to achieving NASA's space and aeronautics program.

## STRATEGY FOR ACHIEVING GOALS

Funding for construction is budgeted in the appropriations which require specific facilities to conduct their programs. Funding for discrete projects required to conduct specific Human Space Flight or Science, Aeronautics, and Technology programs or projects are included in these two appropriations. The Construction of Facilities budget line item in the Mission Support appropriation provides for discrete projects required for components of the basic infrastructure and institutional facilities. The Mission Support appropriation also includes minor revitalization projects (repair and rehabilitation and modernization of existing facilities), minor construction projects, environmental compliance and restoration activities, the design of facilities projects, and advanced planning related to future facilities needs. The narratives for all construction projects are included to identify the total facilities required in FY 1998. The Space Shuttle budget (in the Human Space Flight appropriation), and the Life and Microgravity Sciences and Applications budget and the Aeronautics and Advanced Space Transportation budget (within the Science, Aeronautics and Technology appropriation) include the specific facility projects as program requirements and references the narratives provided in Mission Support for detailed descriptions and justifications.

The Human Space Flight FY 1998 budget request provides discrete projects for restoration of Space Station facilities, including the Shuttle launch pad As surface and slope, repair of Pad A Payload Changeout Room wall and ceiling, and rehabilitation of the 480 volt electrical distribution system for the External Tank Manufacturing Building at the Michoud Assembly Facility. The Science, Aeronautics, and Technology FY 1998 budget request provides discrete projects for rehabilitation and modification of the B2 Test Stand at Stennis Space Center and modifications for the installation of the Bio-Plex at Johnson Space Center.

In Mission Support, funding is requested in FY 1998 for discrete projects to repair and modernize utility and building systems which have reached or exceeded their normal design life. These systems include cooling, mechanical. structural, and electrical distribution at Ames Research Center, Dryden Flight Research Facility, Goddard Space Flight Center, Kennedy Space Center, Lewis Research Center, and Marshall Space Flight Center. Also included is a project at the Jet Propulsion Laboratory to construct a facility in which to consolidate emergency services currently housed in various substandard facilities and trailers.

These facilities are critical to the development and operation of the space transportation system. In addition, they are necessary to support payloads and launch facilities, as well as our aeronautical and aerospace testing capabilities, that also support military and private industry users.

The FY 1998 construction program is required to 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 program included in this request continues the necessary rehabilitation and modification program and a responsive repair program. The minor construction program provides a means to accomplish smaller facility projects which accommodate changes in technical and institutional requirements. The environmental compliance and restoration program is critical to ensuring that statutory environmental requirements are met and that necessary remedial actions are promptly taken.

Funds requested for facility planning and design cover advance planning and design requirements for potential future projects, master planning, facilities studies, engineering report and studies, and the preparation of facility project design drawings and bid specifications. Since pressures continue to mount on the Construction of Facilities resources as the facility base ages, as a preventive measure, funding is also included for two initiatives (conversion to Reliability-Centered Maintenance and Performance-Based Maintenance Contracting) directed at increasing the rate of return of severely constrained Agency resources while keeping the facility infrastructure safe, reliable, and available. These conversions began in FY 1996 and planned to conclude in FY 1998.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 1998 ESTIMATES
SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT
(Thousands of Dollars)

| INSTALIATION AND PROJECT | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| HUMAN **SPACE FLIGHT** | | | | |
| SPACE STATION: | 18.100 | --- | --- | |
| Construction of Addition to Microgravity Development Laboratory (MSFC) | 3.300 | --- | --- | |
| Construction **of** Neutral Buoyancy Laboratory (JSC) | 14,800 | --- | --- | |
| OTHER HUMAN SPACE FLIGHT | 17,400 | 8,300 | 6,800 | |
| Repair of Payload Changeout Room Wall & Ceiling, Pad A (KSC) | --- | --- | 2,200 | MS4-11 |
| Restoration of Pad Surface & Slope, Pad A (KSC) | --- | --- | 1.800 | MS4-14 |
| Rehabilitation of 480V Electrical Distribution System, External Tank Manufacturing Building (MAF) | --- | 2,500 | 2,800 | MS 4-17 |
| Replacement of LC-39 Pad B Chillers (KSC) | --- | 1,800 | --- | |
| Restoration of Pad B Fixed Support Structure Elevator System (KSC) | --- | 1,500 | --- | |
| Restoration of High Pressure Industrial Water Plant (SSC) | --- | 2,500 | --- | |
| Modernize Firex System, Pads A and B (KSC) | 5,000 | --- | --- | |
| Replace Chemical Analysis Facility (KSC) | 7,500 | --- | --- | |
| Replace Space Shuttle Main Engine Processing Facility (KSC) | 4.900 | --- | --- | |
| **Total - Human Space Flight** | **35.500** | **8.300** | **6.800** | |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 1998 ESTIMATES
SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT
(Thousands of Dollars)

| INSTALLATION AND PROJECT | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| **:IEN( AERONAUTICS. AND TECHNOLOGY** | | | | |
| MISSION TO PLANET EARTH | | | | |
| Construction of Earth System Science Building (GSFC) | 17,000 | --- | --- | |
| LIFE & MICROGRAVITY SCIENCE AND APPLICATIONS | | | | |
| Modifications for the Installation of the Bio-Plex (JSC) | --- | --- | 2,000 | MS 4-22 |
| AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY | | | | |
| Rehabilitation and Modification of B2 Test Stand (SSC) | --- | 2,300 | 3.700 | MS4-27 |
| Modifications to Complex "E" to Consolidate Propulsion Testing (SSC) | 10 500 | --- | --- | |
| **Total - Science, Aeronautics and Technology** | **27.500** | **2.300** | **5.700** | |

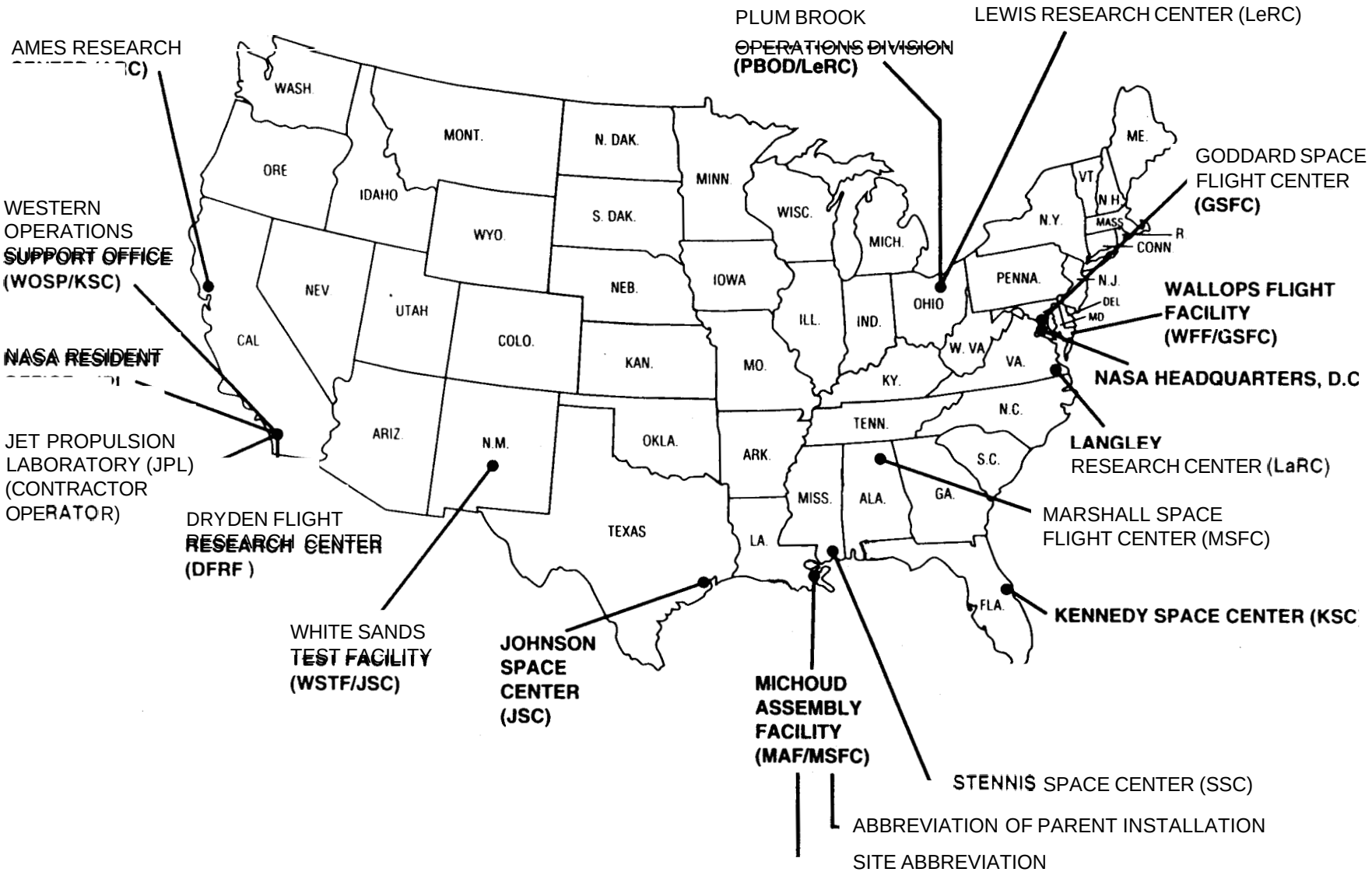
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 1998 ESTIMATES
SUMMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT
(Thousands of Dollars)

| INSTALLATION AND PROJECT | Fiscal Year 1996 | Fiscal Year 1997 | Fiscal Year 1998 | Page Number |
|---|---|---|---|---|
| **MISSION SUPPORT CONSTRUCTION OF FACILITIES (COF)** | | | | |
| Modernization of Process Cooling System, Numerical Aerodynamic Simulation Facility (ARC) | --- | --- | 2.700 | MS 4-32 |
| Rehabilitation and Modification of Hangar/Shop (DFRC) | --- | --- | 2.800 | MS 4-35 |
| Restoration of Chilled Water Distribution System (GSFC) | 3,000 | 4,000 | 2,400 | MS 4-39 |
| Restoration of Space/Terrestrial Application Facility (GSFC) | --- | --- | 4,600 | MS 4-42 |
| Construction of Emergency Services Facility (JPL) | --- | --- | 4,800 | MS 4-45 |
| Upgrade of Utility Annex Chilled Water Plant (KSC) | --- | --- | 5,900 | MS 4-49 |
| Rehabilitation of High Voltage System (LeRC) | --- | --- | 9.400 | MS 4-52 |
| Modification of Chilled Water System (MSFC) | --- | 6,700 | 7.000 | MS 4-55 |
| Modernization of Electrical Distribution System (ARC) | --- | 2,400 | --- | |
| Modification of Aircraft Ramp and Tow Way (DFRC) | --- | 3,000 | --- | |
| Restoration of Hangar Building 4801 (DFRC) | --- | 4,500 | --- | |
| Modernization of Secondary Electrical Systems (GSFC) | --- | 1,500 | --- | |
| Modification of Refrigeration Systems, Various Buildings (JPL) | --- | 2,800 | --- | |
| Rehabilitation of Electrical Distribution System, White Sands Test Facility (JSC) | 1,100 | 2,600 | --- | |
| Rehabilitation of Utility Tunnel Structure and Systems (JSC) | --- | 4.400 | --- | |
| Replacement of DX Units with Central Chilled Water System, Logistics Facility, (KSC) | --- | 1,800 | --- | |
| Rehabilitation of Central Air Equipment Building (LeRC) | 9,000 | 6,500 | --- | |
| Rehabilitation of Condenser Water System, 202/207 Complex (MAF) | --- | 2,100 | --- | |
| Restoration of Flight Systems Research Laboratory (ARC) | 6,300 | --- | --- | |
| Replace Chillers, Various Buildings (JPL) | 4,800 | --- | --- | |
| Replace Main Substation Switchgear and Circuit Breakers (JSC) | 4,200 | --- | --- | |
| Replace 15kV Load Break Switches (KSC) | 1,800 | --- | --- | |

| INSTALLATION AND PROJECT | Fiscal Year 1996 | Fiscal Year 1997 | Fiscal Year 1998 | Page Number |
|---|---|---|---|---|
| **MISSION SUPPORT COF** (continued) | | | | |
| Restoration of High Pressure Air Compressor System (MSFC) | 4,700 | --- | --- | |
| Restoration of Information & Electronic Systems Lab (MSFC) | 6,800 | | | |
| Restoration of Canal Lock (SSC) | 1,400 | | | |
| Restoration of Primary Electrical Distribution System (WFF) | 2,500 | | | |
| Minor Revitalization | 72,540 | 57.900 | 65,700 | MS 4-59 |
| Minor Construction | 3,800 | 3,400 | 1,100 | MS 4-69 |
| Facility, Planning and Design | 10,000 | 18,700 | 19,000 | MS 4-72 |
| Environmental Compliance and Restoration | 37,000 | 33,000 | 34,000 | MS 4-77 |
| *Reduction | -24.000 | --- | --- | |
| MISSION SUPPORT | 144.940 | 155.300 | 159.400 | |
| **TOTAL CONSTRUCTION OF FACILITIES (ALL APPROPRIATIONS)** | **207.940** | 165.900 | 171.900 | |

*In accordance with Appropriation Conference Report 104-384 dated December 7, 1995 accompanying H.R. 2099, $24 million of excess FY 1994 funding was used to fund FY 1996 construction projects.

# LOCATION OF MAJOR AND COMPONENT INSTALLATIONS



RECORDED VALUE OF CAPITAL TYPE PROPERTY
IN HOUSE AND CONTRACTOR-HELD
AS OF SEPTEMBER 30, 1996
(DOLLARS IN THOUSANDS)

| REPORTING INSTALLATION | LAND | BUILDING | OTHER STRUCTURES AND FACILITIES | LEASEHOLD IMPROVEMENTS | TOTAL | EQUIPMENT | FIXED ASSETS IN PROGRESS | GRAND TOTAL |
|---|---|---|---|---|---|---|---|---|
| AMES RESEARCH CENTER | 6,865 | 708.043 | 69,499 | 0 | 784,407 | 353.898 | 93,299 | 1.231 604 |
| ARC MOFFETT FIELD, CA | 2.928 | 652.814 | 30.013 | 0 | 685.755 | 353.898 | 93.299 | 1132952 |
| WIDEN FLIGHT FACILITY EDWARDS, CA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VARIOUS LOCATIONS | 3.937 | 55.229 | 39.486 | 0 | 98.652 | 0 | 0 | 98.652 |
| GODDARD SPACE FLIGHT CENTER | 3.351 | 340,181 | 149.117 | 0 | 492.649 | 824.315 | 971 428 | 2,288,392 |
| GSFC-GREENBELT, MD | 1577 | 227.483 | 44 375 | 0 | 273.435 | 409,762 | 75 837 | 759 034 |
| TRACKING STATIONS NETWORK | 0 | 39,406 | 11,419 | 0 | 50.825 | 230.369 | 376 | 281 570 |
| WFF-WALLOPS ISLAND,VA | 1.774 | 67546 | 88.577 | 0 | 157.897 | 90.792 | 12 892 | 261 581 |
| VARIOUS LOCATIONS | 0 | 5.746 | 4.746 | 0 | 10,492 | 93.392 | 882.323 | 986,207 |
| JET PROPULSION LABORATORY | 1.189 | 229,340 | 151.566 | 666 | 382.761 | 361.387 | 1,724,702 | 2.468850 |
| JPL PASADENA,CA | 1,189 | 229.340 | 151,566 | 666 | 382.761 | 361.387 | 1,724,702 | 2.468850 |
| JOHNSON SPACE CENTER | 11.256 | 374.443 | 135.498 | 154 | 521,351 | 815.465 | 231,207 | 1 568.023 |
| JSC-HOUSTON, TX | 7,309 | 302,727 | 88.891 | 0 | 398.927 | 473.441 | 61.225 | 933593 |
| WHITE Y N B TEST FACILITY LOS CRUCES, NM | 377 | 19,102 | 40,506 | 154 | 60.139 | 0 | 0 | 60,139 |
| VARIOUS LOCATIONS | 3.570 | 52.614 | 6.101 | 0 | 62285 | 342.024 | 169.982 | 574.291 |
| KENNEDY SPACE CENTER | 73.672 | 716,024 | 616,991 | 0 | 1,406,687 | 833,003 | 141,679 | 2,381,369 |
| KSC-CAPE CANAVERAL, FL | 73 672 | 716.024 | 616.991 | 0 | 1,406.687 | 95,609 | 126,846 | 1 629 142 |
| WESTERN TEST RANGE. LOMPOC, CA | 0 | 0 | 0 | 0 | 0 | 3.404 | 0 | 3404 |
| VARIOUS LOCATIONS | 0 | 0 | 0 | 0 | 0 | 733,990 | 14.833 | 748 823 |
| LANGLEY RESEARCH CENTER | 156 | 269534 | 461 819 | 0 | 731,509 | 347,699 | 75 489 | 1 154697 |
| LARC HAMPTON VA | 156 | 269,534 | 461 819 | 0 | 731,509 | 333 158 | 47 975 | 1112642 |
| VARIOUS LOCATIONS | 0 | 0 | 0 | 0 | 0 | 14 541 | 27 514 | 42 055 |
| LEWIS RESEARCH CENTER | 2.621 | 350.122 | 124,556 | 136 | 477.435 | 276.212 | 141,172 | 894819 |
| LERC-CLEVELAND, OH | 316 | 270,504 | 101.717 | 136 | 372.673 | 181 401 | 135 075 | 689 149 |
| PLUM BROOK, SANDUSKY, OH | 2.305 | 79.618 | 22.184 | 0 | 104.107 | 79693 | 0 | 183 800 |
| VARIOUS LOCATIONS | 0 | 0 | 655 | 0 | 655 | 15.118 | 6.097 | 21 870 |
| MARSHALL SPACE FLIGHT CENTER | 7.162 | 402.248 | 209,167 | 0 | 618.577 | 781.813 | 1,396,268 | 2,796,658 |
| MSFC-HUNTSVILLE, AL | 0 | 224.971 | 104.245 | 0 | 329216 | 580,173 | 1.396268 | 2 305.657 |
| MICHOUD ASSEMBLY FACILITY, LA | 7.162 | 172.449 | 94,616 | 0 | 274227 | 77.129 | 0 | 351 356 |
| SLIDELL COMPUTER COMPLEX, LA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VARIOUS LOCATIONS | 0 | 4.828 | 10.306 | 0 | 15.134 | 124.511 | 0 | 139,645 |
| STENNIS SPACE CENTER | 18,080 | 137,664 | 264.340 | 0 | 420,084 | 54.800 | 60.350 | 535234 |
| STENNIS SPACE CENTER | 18,080 | 137,664 | 264.127 | 0 | 419,871 | 54.800 | 60,350 | 535 021 |
| VARIOUS LOCATIONS | 0 | 0 | 213 | 0 | 213 | 0 | 0 | 213 |
| NASA HEADQUARTERS | 0 | 6 | 0 | 0 | 6 | 50,696 | 41.720 | 92.422 |
| NASA HQS WASH, DC | 0 | 6 | 0 | 0 | 6 | 50.696 | 41.720 | 92422 |
| VARIOUS LOCATIONS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DRYDEN FLIGHT RESEARCH CENTER | 0 | 73405 | 33 979 | 0 | 107,384 | 256554 | 5 985 | 369 923 |
| WIDEN FLIGHT FACILITY EDWARDS CA | 0 | 73,405 | 33 979 | 0 | 107,384 | 256347 | 5 985 | 369716 |
| VARIOUS LOCATIONS | 0 | 0 | 0 | 0 | 0 | 207 | 0 | 207 |
| *AGENCY TOTAL* | **124,352** | **3,601,010** | **2,216,532** | **956** | **5,942,850** | **4,955,842** | **4,883,299** | **15,781,991** |

# Human Space Flight

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 1998 ESTIMATES

SUMMARY

HUMAN SPACE FLIGHT

| | Amount (Dollars) | Page Number |
|---|---|---|
| Other Human Space Flight: | | |
| Repair Of Payload Changeout Room Wall & Ceiling, Pad A (KSC) | 2,200,000 | MS 4-11 |
| Restoration of Pad Surface & Slope, Pad A (KSC) | 1,800,000 | MS 4-14 |
| Rehabilitation of 480V Electrical Distribution System, MAF (MSFC) | 2,800,000 | MS 4-17 |
| Total Human Space Flight | 6,800,000 | |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Repair of Pavload Chaneeout Room Wall and Ceiling. Pad A

INSTALIATION: John F. Kennedv Space Center

FY 1998 Estimate: $2,200,000

LOCATION OF PROJECT: Kennedy Space Center, Brevard County. Cape Canaveral, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $220,000 | --- | $ 220,000 |
| Capitalized Investment | --- | $98,995,262 | 98,995,262 |
| Tota l . . . . . | $220,000 | $98,995,262 | $99,215,262 |

SUMMARY PURPOSE AND SCOPE:

The Launch Complex 39 Pad A Payload Changeout Room (PCR) was originally designed and built to provide a controlled environment for pre-flight services of space shuttle hardware. This project replaces damaged structures that now allow contaminants to enter the PCR's controlled space. It also enhances the efficient and effective operation and maintenance of the PCR space and supporting utilities. The PCR is required for Kennedy Space Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

Contamination levels within the PCR have increased significantly. These contaminants enter the PCR via the damaged exterior walls and deteriorated access doors, which can no longer maintain necessary pressurization levels. Friable insulation associated with

mechanical components also contributes to the contamination. This project will prevent the payload processing environment from exceeding acceptable limits for contamination and pressurization capability and becoming a launch constraint.

IMPACT OF DELAY:

Failure to provide timely repair of the PCR structure and supporting mechanical systems will allow contamination levels to exceed acceptable limits. This will hinder space shuttle launch preparation and potentially cause launch delays. Also, operation and maintenance costs associated with keeping the deteriorated structure and mechanical components operating will continue to increase.

PR( DESCRIPTION:

This project replaces damaged PCR wall panels, illuminates the access area within the PCR plenum, replaces the ceiling grid assembly, and replaces or eliminates various leaking access doors. The high efficiency particular air (HEPA) filter housing will be reconfigured to allow safer accessibility.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantitv | Unit Cost | Cost |
|---|---|---|---|---|
| Civil/Structural | Lump Sum(LS) | -- | --- | $1,800,000 |
| Mechanical | LS | --- | --- | 200,000 |
| Electrical | LS | --- | --- | 200.000 |
| Tot. . . . . | | | | $2.200.000 |

LIST OF RELATED GRAPHICS: Figure 1 - Site Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

JOHN F. KENNEDY SPACE CENTER
FISCAL YEAR 1998 ESTIMATES
REPAIR OF PAYLOAD CHANGEOUT ROOM WALL & CEILING, PAD A

SITE PLAN
LC-39 PAD A

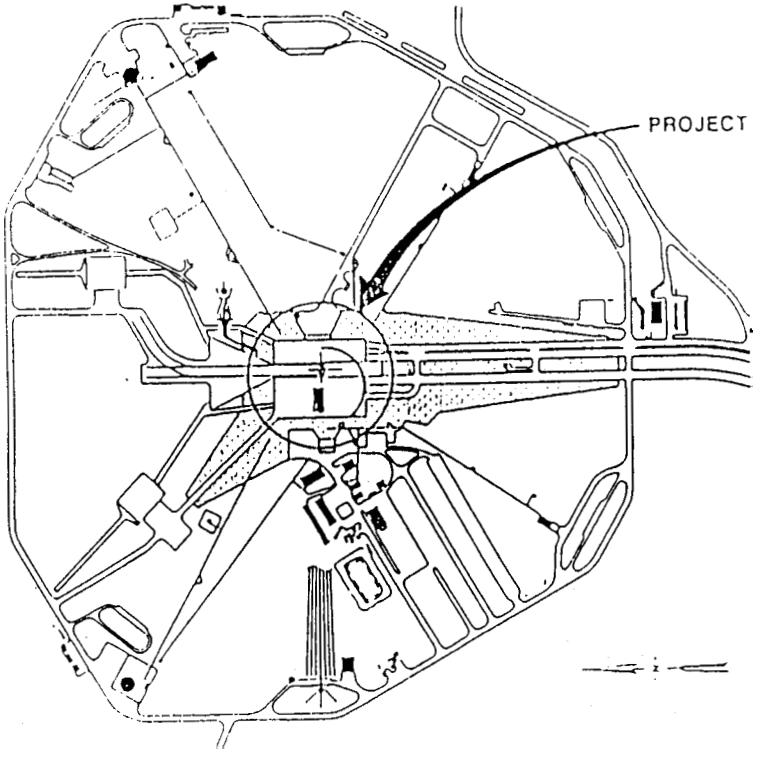



FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

---

PROJECT TITLE: Restoration of Pad Surface and Slope, Pad A

INSTALLATION: John F. Kennedy Space Center

FY 1998 Estimate: $1,800,000

---

LOCATION OF PROJECT: Kennedy Space Center, Brevard County, Cape Canaveral, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $96,000 | --- | $ 96,000 |
| Capitalized Investment | --- | $98.995.262 | 98,995,262 |
| Total | $96,000 | $98,995,262 | $99.09 1.262 |

MARY PURP AND SCOPE:

This project restores the structural concrete of the launch pad surfaces to prevent the ingress of water which accelerates deterioration of subbase materials and imbedded reinforcing steel. Pad A is required for Kennedy Space Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

Pad As concrete surface, slopes, and catacomb areas are over 30 years old, and deteriorated with cracks, spalls, and broken sections that are unsafe for launch operations. The cracks in the pad surface permit launch and rain water to leak into and weaken the underlying compacted fill. Launch vibration and hydrostatic pressure on the undermined slopes cause the concrete panels to crack further and break into pieces. Cracks in the pad surfaces allow acidic launch water to attack the pad rebar, which erodes and results

in spall failures of the catacomb ceiling and a structural weakening of the launch pad. The crawlenvay grid path also has cracks in the substructure, which allows water to undermine the slopes and also attack the catacomb rebar and concrete.

IMPACT OF DELAY

Failure to provide timely repair of the launch pad concrete surfaces will allow the rate of water infiltration and subsequent structural weakening to accelerate, rapidly increasing the ultimate repair cost. Also, the shuttle manifest allows a unique five-month window in January 1998 to implement this project. The next available window will be in the year 2001.

PROJECT DESCRIPTION:

This project repairs cracks in the launch pad concrete surfaces and replaces or repairs fractured and broken sections of concrete. The cracked areas of the pad slopes will be sealed and the broken and raised or "bulged" portions will be removed. The underlying fill will be replaced and recompacted. The subbase under the crawlenvay slabs will also be repaired. Cracks and joints on the pad surface will be sealed. The cracks in the concrete ceiling structure of the catacombs will be repaired.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantitv | Unit Cost | Cost |
|---|---|---|---|---|
| Civil/Structural | LS | --- | --- | $1,800,000 |
| Total | | | | $1,800,000 |

LIST OF RELATED GRAPHICS: Figure l-Site Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT None

# JOHN F. KENNEDY SPACE CENTER
# FISCAL YEAR 1998 ESTIMATES
# RESTORATION OF PAD SURFACE & SLOPE, PAD A

## SITE PLAN
## LC-39 PAD A

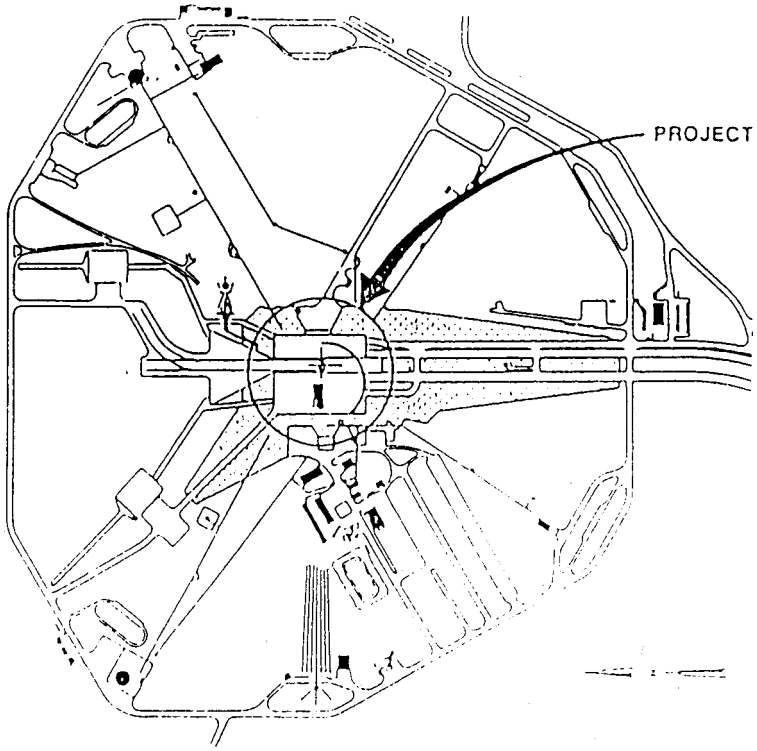



FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Rehabilitation of 480V Electrical Distribution Svstem. External Tank Manufacturing Building

INSTALIATION: Michoud Assemblv Facility

FY 1998 ESTIMATE: $2,800,000

LOCATION OF PROJECT New Orleans, Orleans Parish, Louisiana

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $382,000 | $ 2,500,000 | $ 2,882,000 |
| Capitalized Investment | --- | 54,444,830 | 54,444,830 |
| Total | $——— | $56,944,830 | $57,326,830 |

SUMMARY PURPOSE AND SCOPE:

This project rehabilitates and modifies the 480V electrical distribution system which supports critical External Tank (ET) manufacturing operations in the Mechanical Sub-Assembly, Intertank, and Dome Assembly areas of the ET Manufacturing Building (103).This project specifically replaces the electrical distribution system associated with substations 3, 4, and 5. It is required to restore quality and reliability to the electrical power system and avoid costly piecemeal repairs. Building 103 is required for the Michoud Assembly Facility to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

The 480V electrical distribution system in Building 103was originally installed in the 1940's. Exposed distribution feeders resulting from cracked insulation and "spot" overloads combine to create potential production shutdowns. Existing bus ducts are inaccessible for maintenance. Feeder taps to fan houses lack overcurrent protection. Main distribution and sub-distribution panels and associated breakers are obsolete. Existing grounding does not meet the National Electric Code (NEC) nor current design standards. An in-house long range electrical plan and a subsequent A/E study recommend upgrade of the 480V power distribution system. This project is needed to provide a safe and reliable 480V electrical distribution system from substations 3, 4, and 5 to the Mechanical Sub-Assembly, Intertank. and Dome Assembly areas of Building 103. It continues the systematic rehabilitation of older high-voltage systems in critical production areas.

IMPACT OF DELAY:

Failure to rehabilitate exposed feeders, hot spots, and improper grounding may likely result in production shutdowns in the Mechanical Sub-Assembly, Intertank, and Dome Assembly areas of the External Tank manufacturing operations.

PROJECT DESCRIPTION:

This project installs new main distribution and sub-distribution power panels and new transformers. New electrical distribution feeders will be routed in cable trays for ease of maintenance. Electrical distribution circuits will be designed to eliminate the need for bus ducts. The new distribution system will be tied into substation switch gear and the old distribution system will be demolished.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit cost | Cost |
|---|---|---|---|---|
| Electrical | LS | --- | --- | $2,800,000 |
| Total | | | | $2.800.000 |

LIST OF RELATED GRAPHICS: Figure 1 - Site Plan

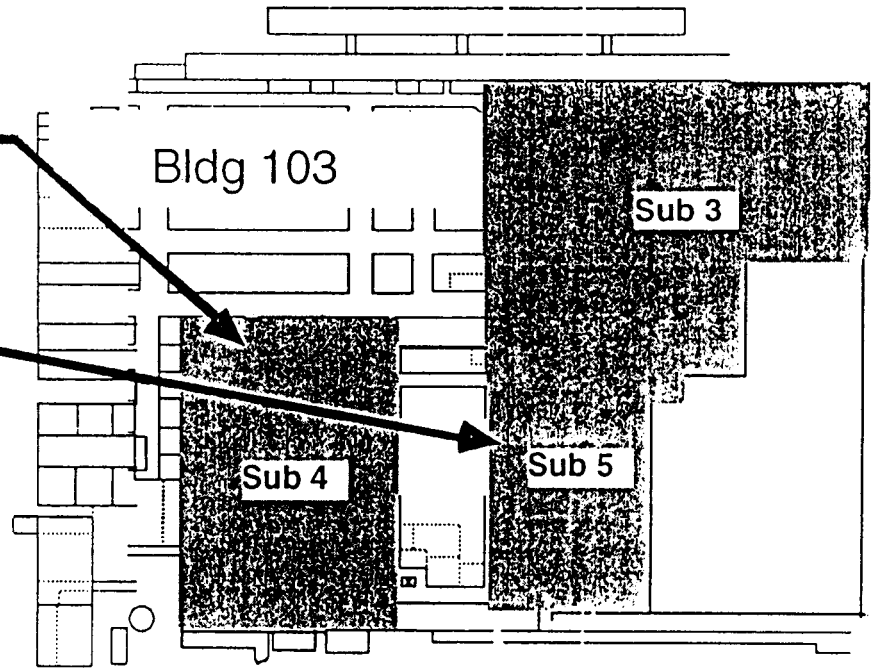
OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None. However, future CoF funding in the amount of $3,800,000 will be required in FY 1999-2000 to rehabilitate the 480V electrical distribution system in the remaining areas of Building 103.

# MICHOUD ASSEMBLY FACILITY
# FISCAL YEAR 1998 ESTIMATES
# REHABILITATION OF 480V ELECTRICAL DISTRIBUTION SYSTEM

## SITE PLAN

- Substation 4
  - LH2 Barrel Mechanical
  - Rotational Fixture
- Substation 3 and 5
  - Weld Sub-Assembly
  - Mechanical Assembly
  - Mechanical Sub-Assembly
  - Intertank Assembly
  - Dome Assembly




**EXTERNAL TANK MANUFACTURING BUILDING**

**FIGURE 1**

Science, Aeronautics,
and Technology

FISCAL YEAR 1998 ESTIMATES

SUMMARY

SCIENCE, AERONAUTICS AND TECHNOLOGY

| INSTALLATION AND PROJECT | Amount (Dollars) | Page Number |
|---|---|---|
| **SCIENCE, AERONAUTICS, AND TECHNOLOGY** | | |
| LIFE & MICROGRAVITY SCIENCE AND APPLICATIONS | | |
| Modifications for the Installation of the Bio-Plex (JSC) | 2,000,000 | MS 4-22 |
| AERONAUTICS AND SPACE TRANSPORTATION TECHNOLOGY | | |
| Rehabilitation and Modification of B2 Test Stand (SSC) | 3,700.000 | MS 4-27 |
| **Total - Science, Aeronautics, and Technology** | **5.700.000** | |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Modification for the Installation of the Bio-Plex (29)

INSTALLATION: Lvndon B. Johnson Space Center

FY 1998 Estimate: $2,000,000

LOCATION OF PROJECT. Johnson Space Center, Harris County, Houston, Texas

COGNIZANT HEADQUARTERS OFFICE: Office of Life and Microgravity Sciences and Applications

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $160,000 | --- | $ 160,000 |
| Capitalized Investment | --- | $10,987,891 | 10,987,891 |
| Total | $160,000 | $10,987,891 | $11,147,891 |

**SUMMARY** PURPOSE AND SCOPE:

This project is required to develop a test facility capable of evaluating large-scale bio-regenerative planetary life support systems with human test crews for long-duration testing. This project provides for the installation of the Bio-Regenerative Planetary Life Support Systems Test Complex (Bio-Plex) in the rotunda and east service wings of the Weightless Environmental Training Facility (WET-F), Building 29.

The Bio-Plex facility will be the Agency's advanced planetary life support test facility sponsored by the Office of Life and Microgravity Sciences and Applications (OLMSA) in support of the Human Exploration and Development of Space (HEDS) Enterprise. This project will play a key role in developing the Bio-Plex Facility's capabilities to evaluate life support technologies for future manned missions.

## PROJECT JUSTIFICATION

NASA's Advanced Life Support Program is developing a test facility capable of evaluating large-scale bio-regenerative planetary life support systems with human test crews for long-duration testing. The existing Human-Related Test Facility is located in the Botanical Sciences Laboratory, Building 241. Building 241 is a small, remote facility with inadequate space, power, and cooling available to meet the needs of the new Bio-Plex. The WET-F is being relocated from Building 29 to the Sonny Carter Training Facility, leaving most of the rotunda and east service wings of Building 29 unoccupied. Building 29 is located within the main mall area of the Johnson Space Center and there is enough physical space, power and chilled water available to meet the needs of the Bio-Plex. A study found that by relocating the Bio-Plex to Building 29 instead of installing it at Building 241, there will be a construction cost savings of $1,800,000.

## IMPACT OF DELAY

If the chambers are not installed by March 1998 and the system is not operational by January 1999, the capabilities for evaluating large-scale bioregenerative planetary life support systems with human test crews for long durations will be jeopardized. Delay of this project would adversely impact the support which the Bio-Plex is intended to provide to the HEDS Enterprise.

## PROJECT DESCRIPTION:

This project provides for the installation of the Bio-Plex in the rotunda and east service wings of the WET-F, Building 29. Modifications include running new electrical feeders from the Utility Tunnel System between Buildings 4 and 7 to Building 29. running additional chilled water to Building 29 from the Utility Tunnel System, installing two new, 1,500-KVA transformers. installing a 400-KW generator, and installing a 90-ton emergency chiller. Other modifications include installing a transfer switch, switchgear. a motor control center and three variable-speed chilled water pumps. Approximately 2,800 square meters of wet pipe automatic fire sprinkler system will be installed along with approximately 45 foundation drilled piers and a pre-cast aggregate facing panel enclosure. Additionally, walls within the east service wing will be relocated and the lighting, power, and plumbing will be rearranged to accommodate the new laboratories.

## PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Site & Civil | LS | --- | --- | $815,000 |
| Mechanical | LS | --- | --- | 340,000 |
| Electrical | LS | --- | --- | 845,000 |
| Total | | | | $2,000,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Site Plan Figure 2 - Proposed Layout

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None.

**LYNDON B. JOHNSON SPACE CENTER**
**FISCAL YEAR 1998 ESTIMATES**
**MODIFICATIONS FOR THE INSTALLATION OF THE BIO-PLEX (29)**

**SITE PLAN**

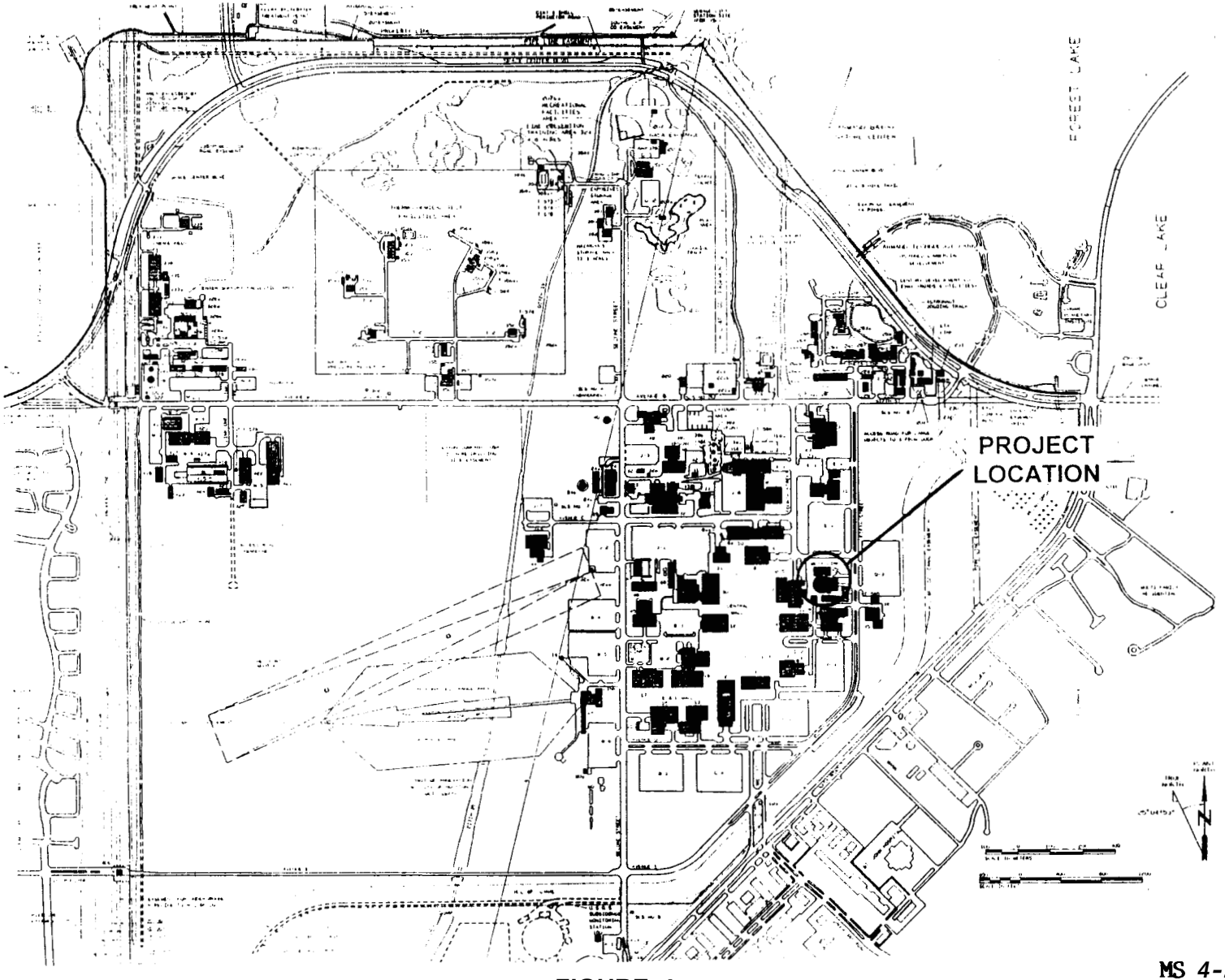



**FIGURE 1**

LYNDON B. JOHNSON SPACE CENTER
FISCAL YEAR 1998 ESTIMATES
MODIFICATIONS FOR THE INSTALLATION OF THE BIO-PLEX (29)

PROPOSED LAYOUT

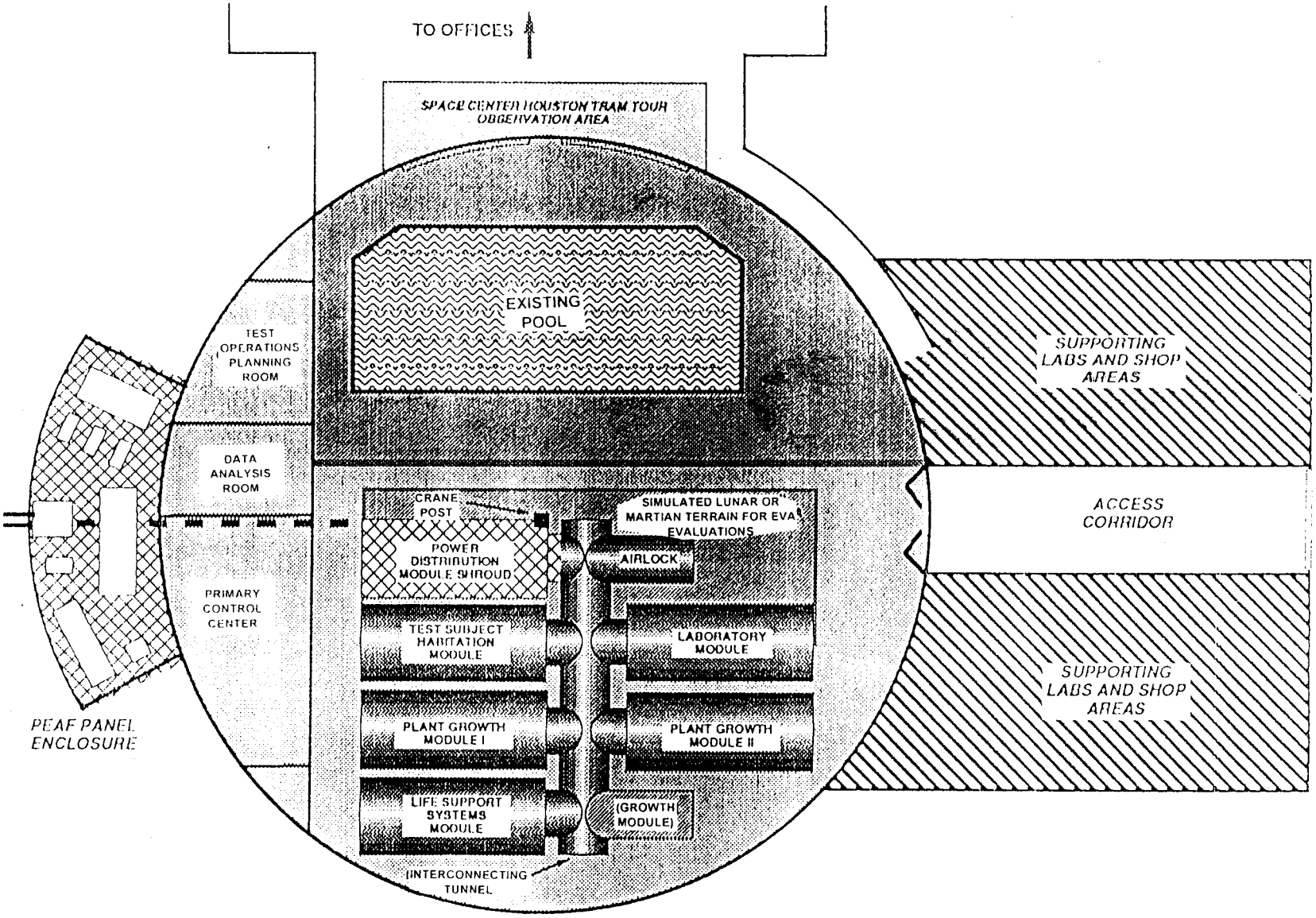



FIGURE 2

MS 4-26

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

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PR TITLE: habilitation and t of B-2 Test Stand

INSTALLATION: John C. Stennis Space Center

FY 1998 Estimate: $3.700.000

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LOCATION OF PROJECT: Stennis Space Center, Hancock County, Mississippi

COGNIZANT HEADQUARTERS OFFICE: Office of Space Access and Technology

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $250,000 | $ 900,000 | $ 1,150,000 |
| Capitalized Investment | --- | 31.473.926 | 31.473.025 |
| Total | $250.000 | $32.373.926 | $32.623.025 |

SUMMARY PURPOSE AND SCOPE:

This project rehabilitates and upgrades critical but deteriorated systems in the B-2 Test Stand. It is required to support Reusable Launch Vehicle (RLV) testing activities in the near future, and is an integral part of NASA's plan to establish Stennis Space Center (SSC) as the Center of Excellence for Propulsion Testing. B-2 Test Stand will also be available to support other programs such as the Evolved Expendable Launch Vehicle (EELV), advanced space technologies, commercial propulsion systems testing, and other future propulsion systems testing.

PROJECT JUSTIFICATION:

SSC has been designated the Center of Excellence for Propulsion Testing as a direct result of the Zero Based Review (ZBR) recommendations. In order to fulfill this role, SSC needs to rehabilitate and upgrade several critical but deteriorated systems in the B-2 Test Stand. Although recognized as a world class facility, the B-2 Test Stand over the years has significantly deteriorated in condition and reliability. Its essential systems and structure need to be restored to reliable and safe working conditions in order to support both near and long term propulsion testing activities.

IMPACT OF DELAY

Unless rehabilitated and modified, the B-2 Test Stand cannot be safely and reliably operated to support RLV and other planned rocket propulsion and advanced space technology testing activities. Failure to do this project will cause major disruptions to the schedules of the planned testing activities and unacceptable cost growth to associated programs.

PROJECT DESCRIPTION:

This project replaces structural elements of the test stand and provides corrosion protection. The flame deflector will be flushed and deteriorated piping segments, connectors, and supply manifolds will be rehabilitated or replaced as required. Nozzles and piping for the deluge system will be repaired or replaced. Safety eyewash stations and supply piping will be installed at various levels to replace unusable systems. Nitrogen and helium purge protection will be restored to critical propellant systems to prevent further deterioration. Electrical power will be reconnected to lighting and other systems. Control wiring and supporting cable trays to minimum control points on the test stand will be replaced. Elevator controls will be repaired and the master facility panel will be upgraded. Other repairs not explicity identified in this paragraph, but which may be required to correct hidden deficiencies that are not discovered may be undertaken.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Civil/Structural | LS | --- | --- | $1,800,000 |
| Electrical | LS | --- | --- | 300,000 |
| Mechanical | LS | --- | --- | 1,600,000 |
| Total | | | | $3,700,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

# STENNIS SPACE CENTER
# FISCAL YEAR 1998 ESTIMATES
# REHABILITATION AND MODIFICATION OF B-2 TEST STAND

## LOCATION PLAN

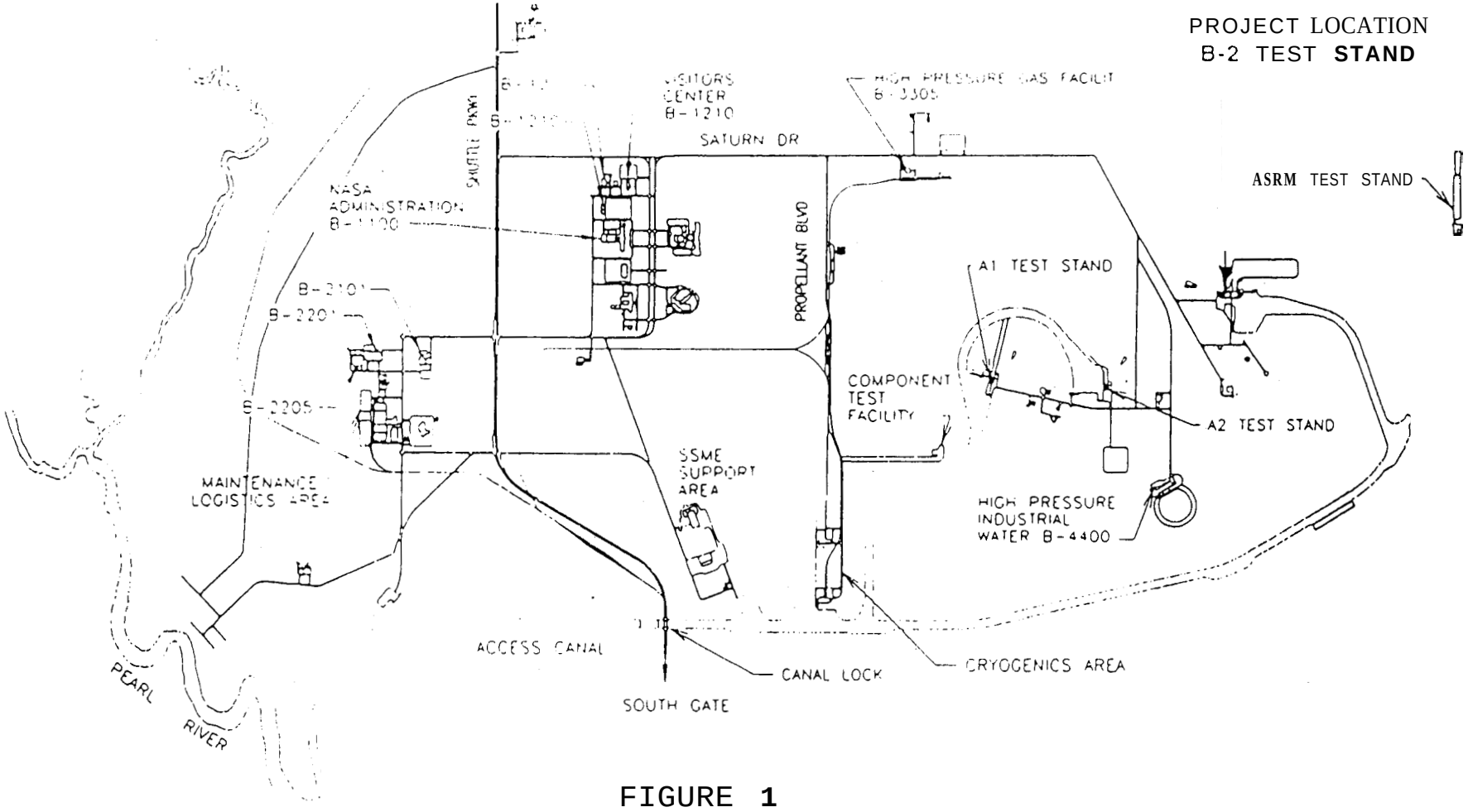


FIGURE 1

Mission Support

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MISSION SUPPORT CONSTRUCTION OF FACILITIES
FISCAL YEAR 1998 ESTIMATES

SUMMARY OF RESOURCE REQUIREMENTs
(Thousands of Dollars)

| | FY 1996 | FY 1997 | FY 1998 | Page Number |
|---|---|---|---|---|
| Discrete Projects | 45,600 | 42,300 | 39,600 | MS 4-31 |
| Minor Revitalization | 72,540 | 57,900 | 65,700 | MS 4-59 |
| Minor Construction | 3,800 | 3,400 | 1,100 | MS4-69 |
| Facility, Planning and Design | 10,000 | 18,700 | 19,000 | MS 4-72 |
| Environmental Compliance and Restoration | 37,000 | 33.000 | 34,000 | MS 4-77 |
| *Reduction | (24,000) | --- | --- | |
| TOTAL | 144 940 | 155,300 | 159,400 | |

*In accordance with Appropriation Conference Report 104-384 dated December 7, 1995 accompanying H.R. 2099, $24 million of excess FY 1994 funding was used to fund FY 1996 construction projects.

| Distribution of Program Amount bv Installation | | | |
|---|---|---|---|
| Lyndon B. Johnson Space Center | 13,955 | 14,000 | 7,000 |
| John F. Kennedy Space Center | 13,100 | 8,200 | 18,100 |
| George C. Marshall Space Center | 18,030 | 20,500 | 24,700 |
| John C. Stennis Space Center | 7,400 | 4,600 | 7,500 |
| Ames Research Center | 11,830 | 9,300 | 8,300 |
| Dryden Flight Research Center | 4,170 | 12.700 | 6,400 |
| Langley Research Center | 8,545 | 7,200 | 6,100 |
| Lewis Research Center | 19,265 | 16,600 | 17.800 |
| Goddard Space Flight Center | 13,875 | 20,300 | 18,100 |
| Jet Propulsion Laboratory | 16,300 | 18,000 | 17,700 |
| Various Locations | 18.470 | 23.900 | 27.700 |
| TOTAL | 144 940 | 155,300 | 159,400 |

FISCAL YEAR 1998 ESTIMATES

SUMMARY

MISSION SUPPORT

| | Amount (Dollars) | Page Number |
|---|---|---|
| **MISSION SUPPORT CRETE PROJECTS** | | |
| 1 dern zatic of Process li Sy Numerical Aerod | | |
| i i F: ilit ) | 2,700,000 | MS 4-32 |
| I h b and :at f Hangar (DFRC) | 2,800,000 | MS 4-35 |
| Restoration of : W: Distribution System (GSFC) | 2,400,000 | MS 4-39 |
| toration of Space/ erestrial pl t Facilit (GSFC) | 4,600,000 | MS 4-42 |
| Construction of F n Services Facility (J | 4,800,000 | MS 4-45 |
| Jpgr of Utility Annex Chilled Water Plant (KSC) | 5,900,000 | MS 4-49 |
| t of High V System (LeRC) | 9,400,000 | MS 4-52 |
| difi of ll W: t t (MSFC) | 7,000,000 | MS 4-55 |
| TOTAL DISCRETE PROJECTS | 39,600,000 | |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Modernization of Process Cooling System, Numerical Aerodynamic Simulation Facility

INSTALLATION: Ames Research Center

FY 1998 Estimate: $2,700,000

LOCATION OF PROJECT: Moffett Field, Santa Clara County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Aeronautics

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $200,000 | --- | $ 200.000 |
| Capitalized Investment | --- | $39.866.601 | 39.866.601 |
| Total | $200,000 | $39,866,601 | $40,066,601 |

SUMMARY PURPOSE AND SCOPE:

This project will significantly increase the operational reliability of the Numerical Aerodynamic Simulation Facility (NASF) by providing an uninterrupted supply of chilled water required by the critical-task super computers and other water-cooled equipment in Building N-258. Work includes installation of a thermal energy storage system, new non-chlorofluorocarbon (CFC) high energy efficiency chillers, and chilled water piping modifications to reduce energy consumption and improve system reliability. The NASF is required for Ames Research Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

Ames Research Center is NASA's Center of Excellence for Information Technology and the NASF (Building N-258) is the "heart" of its information system structure. The facility houses the Von Nuemann and Eagle Cray C-90 supercomputers along with data storage, communication, and auxiliary equipment used by both local and national researchers networked into the systems.

The supercomputers and much of the other equipment are water-cooled, requiring an uninterrupted supply of chilled water to stay in operation. Loss of chilled water will cause the supercomputers to shut down within five minutes, disrupting the researchers tied into the computers. Even a brief shutdown causes loss of research data as well as hours of time to bring the computers back up. The critical nature of the computer load requires simultaneous operation of two chillers at all times. This results in excessive power consumption and accelerated chiller wear. The chillers are worn and have a remaining life projection of less than three years, increasing the likelihood of chiller failure and system shutdown.

This project greatly reduces the risk of chiller failure and also reduces the energy consumption of Building N-258, bringing it into compliance with Federal mandates to reduce overall energy use at NASA operated buildings. In addition, it replaces CFC refrigerant chillers with non-ozone-depleting refrigerant chillers.

IMPACT OF DELAY

Delay of this project will result in loss of critical research data and downtime for the supercomputers of the NASF. This disrupts the work of a large number of researchers tied into this facility and the distribution of their research data Nationwide. Significant reductions in energy consumption and operations and maintenance costs will not be realized. The continued use of an expired refrigerant will have detrimental effects on the environment and will be increasingly expensive to stockpile for continued future use.

PROJECT DESCRIPTION:

This project replaces the four existing 700-ton chillers in Building N-258 with four new 500-ton chillers which use a non-ozone-depleting refrigerant. The project also provides an alternate electrical feed and installs a new thermal energy storage system to serve as emergency backup to the chillers.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Electrical and Communications | Ls | --- | --- | $1,150,000 |
| Mechanical and Plumbing | Ls | --- | --- | 1,500,000 |
| Hazardous Materials Removal | Ls | --- | --- | 20,000 |
| Systems Testing | LS | --- | --- | 30,000 |
| Total | | | | $2,700,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

AMES RESEARCH CENTER
FISCAL YEAR 1998 ESTIMATES
MODERNIZATION OF PROCESS COOLING SYSTEM, NASF

LOCATION PLAN

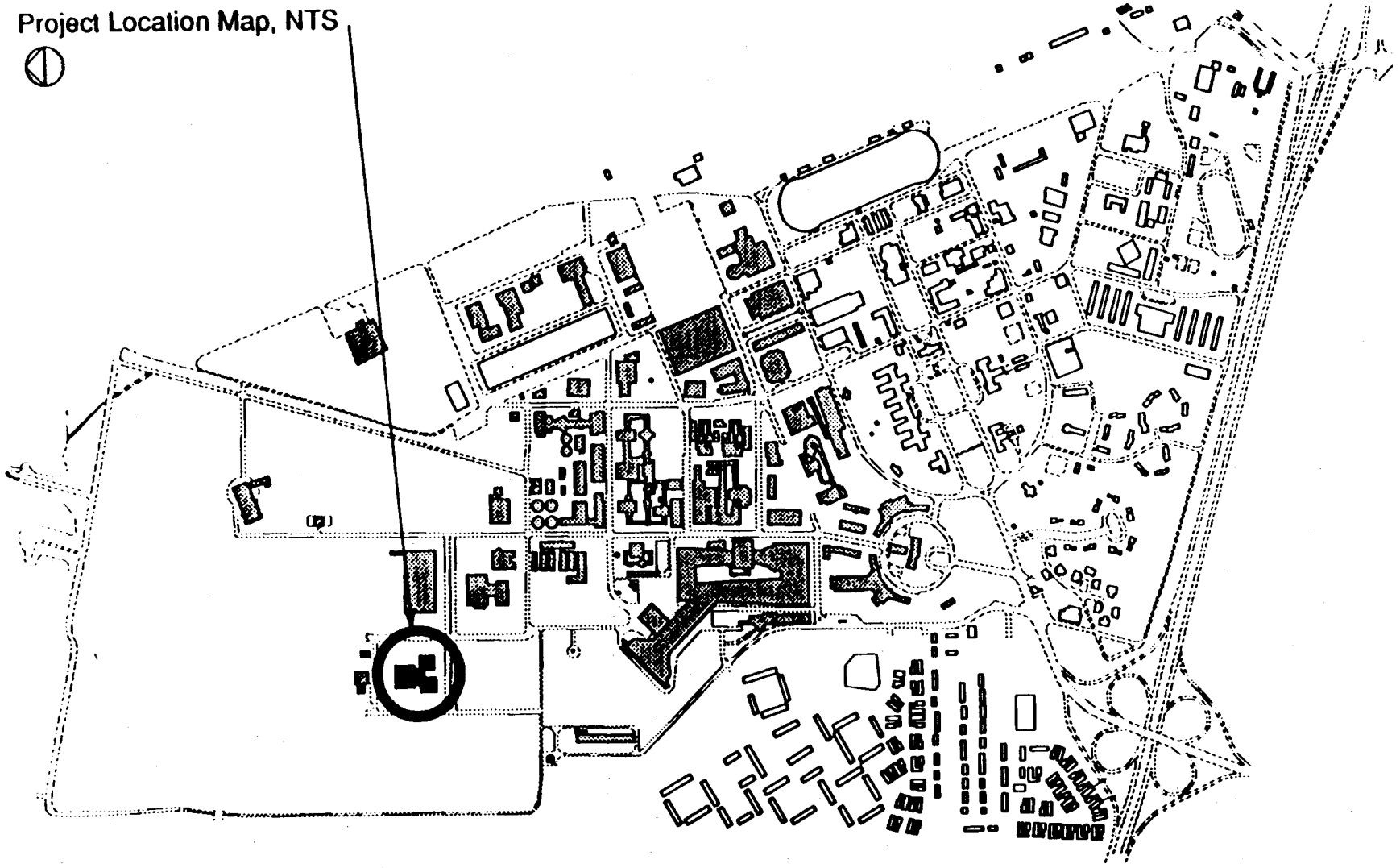


FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Rehabilitation arid Modification of Hangar/Shop

INSTALLATION: Dryden Flight Research Center

FY 1998 Estimate: $2.800.000

LOCATION OF PROJECT: Edwards Air Force Base, Kern County, CA

COGNIZANT HEADQUARTERS OFFICE: Office of Aeronautics

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $224.000 | --- | $ 224,000 |
| Capitalized Investment | ___-- | $1,623,562 | 1,623,562 |
| Total | $224,000 | $1,623,562 | $1,847,562 |

SUMMARY PURPOSE AND SCOPE:

This project rehabilitates and modifies Hangar/Shop Building 4823, which supports aircraft modification and maintenance functions critical to flight research at Dryden Flight Research Facility. This project repairs and reinforces the structure for seismic safety, modernizes utility systems that are old and deteriorated, and slightly expands the facility to accommodate larger aircraft and centralize related **shop** functions. This facility is required for the Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

Dryden is located near the San Andreas fault. This hangar will not withstand a major earthquake in its current condition and needs major structural modifications to meet seismic safety standards. The probable consequences of a major earthquake include injury or death and loss of irreplaceable one-of-a-kind, research aircraft. This project will minimize these consequences. Rehabilitation is needed to meet current building codes for environmental, occupational health and safety, fire protection, disabled-employee access, and energy conservation requirements.

Hangar B4823 is Dryden's primary facility for aircraft maintenance and modification. Various related aircraft maintenance functions are currently scattered around the Center. Lack of centralized shop facilities in close proximity to Hangar 4823 is very inefficient, resulting in lost time for travel between shops and the hangar when tools, equipment, or parts are needed to work on aircraft. The dispersion of personnel hinders creative problem solving, cross training, and cross utilization of personnel among shops. This project locates all shops in a single maintenance facility which includes a substantial hangar, greatly increasing efficiency and productivity. Hangar B4823 needs to be slightly enlarged so that more of Dryden's aircraft can be totally enclosed when being maintained.

IMPACT OF DELAY:

Delay of this project would extend the risk to building occupants and unique, extremely high value aircraft in the event of an earthquake at or near Dryden. The Center would continue its inefficient practice of piecemeal repairs and maintenance to various aircraft, and pay more for energy and maintenance than necessary. Delaying this project will increase the exposure of certain aircraft to the elements because they cannot be totally enclosed in the hangar during modification and maintenance.

PROJECT DESCRIPTION:

This project repairs and reinforces the hangar structure to comply with current seismic and other life safety codes. Utility systems will be modernized, including electrical: mechanical: heating, ventilating, and air conditioning: fire suppression: lighting: water: sewer: storm drainage: and the compressed air system. Lead-based paint will be removed and PCB-filled light fixtures will be replaced. The facility will be enlarged by the addition of a 7.6 meter annex so it can fully accommodate standard-size aircraft and the welding shop can be moved to this building. Related functions to be centralized in this building include the sheet metal shop, machine shop, welding shop, fluids lab, composite shop, non-destructive inspection lab, the chemical crib, and the machinery computer-aided design (CAD) room.

PROJECT COST ESTIMATE:

| | Unit of Measure | Unit Quantitv | Cost | cost |
|---|---|---|---|---|
| Site **Work** | LS | --- | --- | $ 280,000 |
| Architectural/Structural | Ls | --- | --- | 1,420,000 |
| Mechanical | Ls | --- | --- | 500,000 |
| Electrical | LS | --- | --- | 600.000 |
| Total | | | | $2.800.000 |

LIST OF RELATED GRAPHICS: Figure **1** - Location Plan

OTHER EQUIPMENT SUMMARY: Communications and security equipment **is** estimated at $50,000.

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

# DRYDEN FLIGHT RESEARCH CENTER
# FISCAL YEAR 1998 ESTIMATES
# REHABILITATION AND MODIFICATION OF HANGAR/SHOP

## LOCATION PLAN

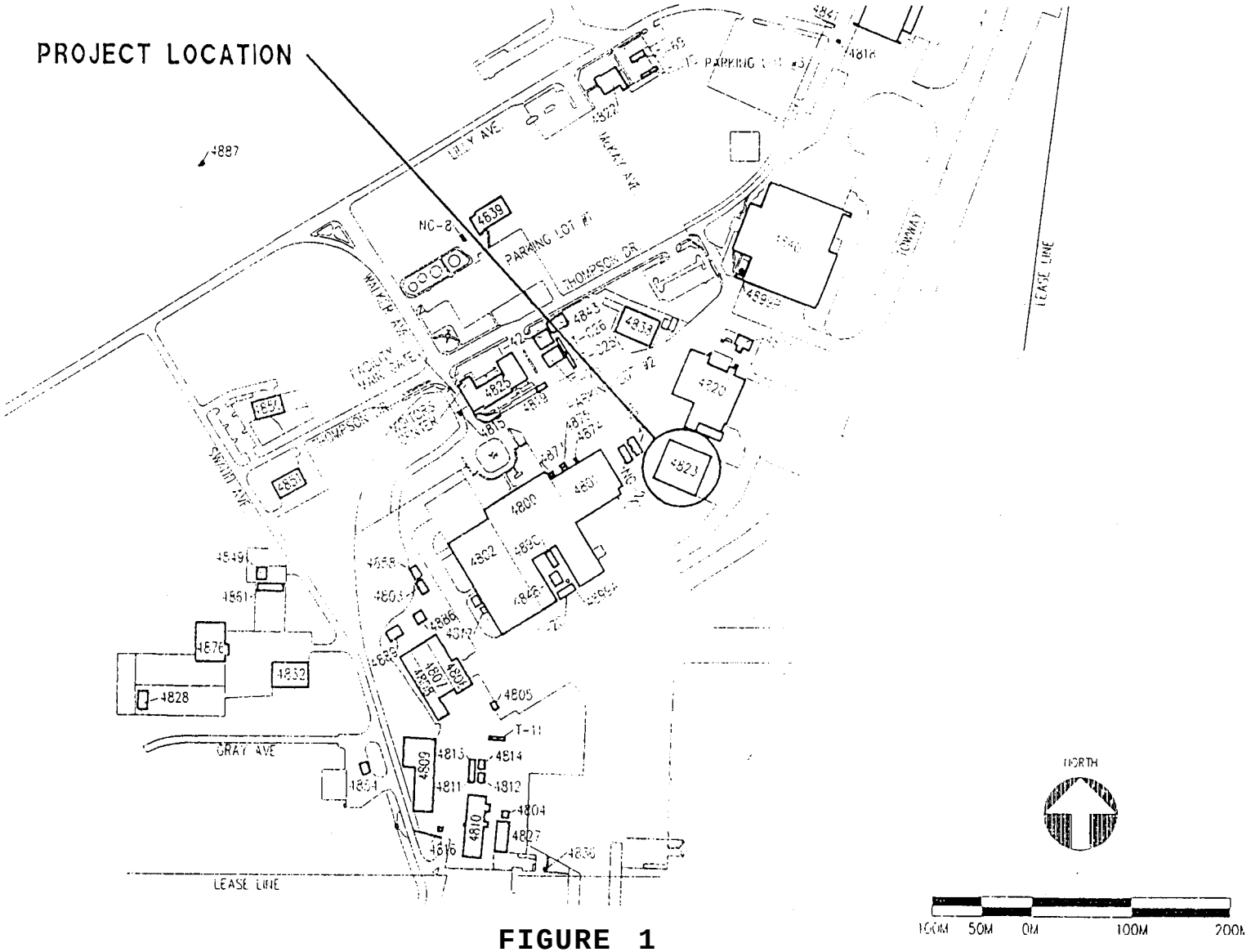


FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Restoration of Chilled Water Distribution Svstem

INSTALLATION: Goddard Space Flight Center

FY 1998 ESTIMATE: $2,400,000

LOCATION OF PROJECT Greenbelt, Prince George's County, Maryland

COGNIZANT HEADQUARTERS OFFICE: Office of Mission to Planet Earth

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $663,000 | $7,000,000 | $ 7,663,000 |
| Capitalized Investment | ... | 4,990,377 | 4,990,377 |
| Total | $663,000 | $11,990,377 | $12,653,377 |

SUMMARY PURPOSE AND SCOPE:

This project continues the restoration of major segments of the chilled water distribution system at the Goddard Space Flight Center (GSFC).The project replaces underground piping that is old and undersized, and installs shutoff valves. This segment of the chilled water distribution system supports facilities required for GSFC to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

GSFC has experienced serious operational problems with the central chilled water distribution system. The underground chilled water piping to be replaced is approximately 30 years old. The pipes and valves have deteriorated and are leaking substantially. The modernization of the central chilled water plant provides new secondary pumps which will boost the pipe distribution pressure and

add even more stress to the system. Pipe sizes in several sections of the system are inadequate for existing as well as future design flow rates. Some critical buildings do not have adequate redundancy in the event of a chilled water service failure.

IMPACT OF DELAY:

Delay of this project will result in continued leaking and failures due to old piping and increasing pressures. Some portions of the system will experience flow deficiencies unless pipe sizes are increased. As a result, some buildings will have inadequate chilled water quantities and air conditioning capacity causing shutdown of mission critical and technical support operations.

PROJECT DESCRIPTION:

This project replaces and upgrades various segments of the underground chilled water distribution piping and provides redundant circuits to improve reliability. The scope will include the section of pipe near Building 23 that completes the main eastern loop: the installation of a redundant header from Minitrack Road to Building 10/15/29; and the backup feed to Building 13 required to protect against single point failure shutdown. Work includes installing shutoff valves at connection points in the new piping, and replacing chilled water supply and return lines to various buildings up to and including the isolation valves inside the buildings. New piping will be sized to support current and future loads as well as provide redundancy for other lines. The project includes all site work required for excavation, rerouting other utilities, backfilling, and resurfacing associated with piping work. Asbestos insulation on existing piping will be removed to the extent necessary to perform the work.

PROJECT COST ESTIMATE:

| | Unit of Measure | Unit Quantity | Cost | Cost |
|---|---|---|---|---|
| Section Near Building 23 | Ls | --- | --- | $ 800,000 |
| Redundant Header to Building 10/15/29 | LS | --- | --- | 700,000 |
| Backup Feed to Building 13 | Ls | --- | --- | 900,000 |
| Total | | | | $2,400,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None. However, additional funding will be required in future years to restore other segments of the chilled water distribution system.

# GODDARD SPACE FLIGHT CENTER
# FISCAL YEAR 1998 ESTIMATES
# RESTORATION OF CHILLED WATER DISTRIBUTION SYSTEM

## LOCATION PLAN

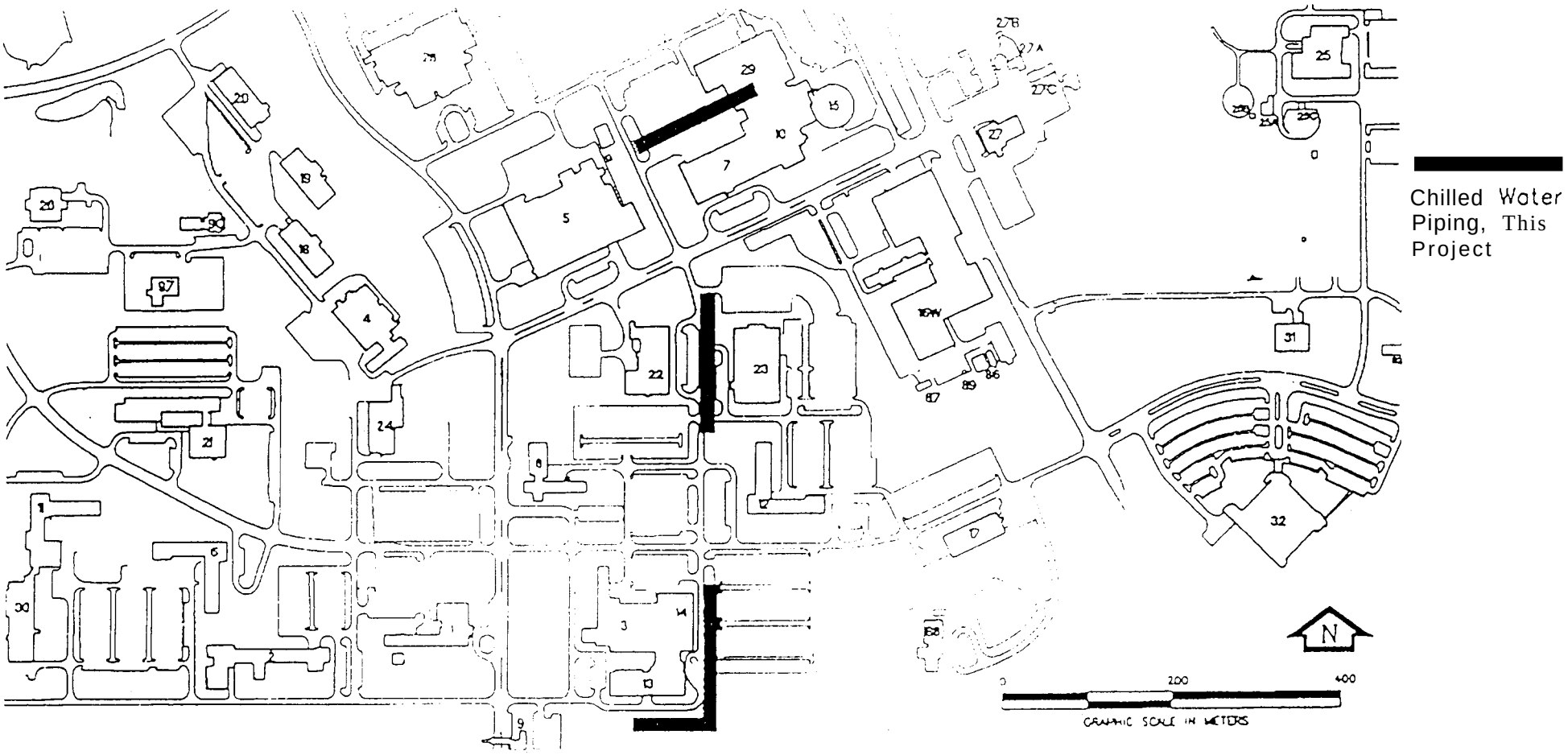


FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Restoration of Space/Terrestrial Applications Facility

INSTALLATION: Goddard Space Flight Center

FY 1998 CoF ESTIMATE: $4.600.000

LOCATION OF PROJECT: Greenbelt, Prince George's County, Maryland

COGNIZANT HEADQUARTERS OFFICE: Office of Mission to Planet Earth

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific CoF Funding | $560,000 | --- | $ 560,000 |
| Capitalized Investment | --- | $7,982,876 | 7,982,876 |
| Total | $560,000 | $7,982,876 | $8,542,876 |

SUMMARY PURPOSE AND SCOPE:

This project restores portions of architectural, mechanical, electrical, and fire protection/detection systems in the Space and Terrestrial Application Facility, Building 22. The project corrects exterior and interior building system deficiencies in order to effectively support research operations conducted in this facility. Building 22 is required for Goddard Space Flight Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

Building 22 has been in service for 30 years. The existing systems have deteriorated and are beyond their projected useful life, which ranges from 20 to 30 years for critical mechanical and electrical system components. It is essential to restore those components likely to fail to maintain reliable support of the GSFC mission.

The functions, operations, and requirements within the building have changed continuously over 30 years, resulting in many modifications. These modifications satisfied immediate isolated demands and in many cases connect new work to old systems to serve localized needs. At this time the facility is not in compliance with current building codes. Operational requirements and budget constraints have severely strained system capabilities, increasing the risk of failure. This project corrects building problems that pose the greatest risk to safety, systems capacities, and reliable facility service.

IMPACT OF DELAY:

System breakdown could occur at any time, resulting in emergency repair/replacement. Building 22 conducts research critical to the GSFC mission. Any unanticipated outage in the facility would seriously impact research operations.

JE( T DESCRIPTION

This project restores 14,52 1 square meters in Building 22. Interior improvements include bringing elevators into compliance with safety, electrical, and accessibility codes and renovating ceilings, floors, and restrooms. Mechanical systems improvements include repairs to induction systems, improving the constant volume distribution systems, rationalizing exhaust systems, removing abandoned equipment, and completing the energy management and control system for the building. Electrical systems improvements include replacing the building load center, motor control center and transformers, as well as some electrical distribution panels, wiring, and conduit. Fire detection system improvements include demolishing the current system and replacing it with a system compatible with the type used centenvide. Fire protection systems will be modified as required incidental to architectural, mechanical, and electrical modifications. The work also includes exterior repairs to wall systems, entrances, and roof systems.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantitv | Unit Cost | Cost |
|---|---|---|---|---|
| Architectural | LS | --- | --- | 1,500,000 |
| Mechanical | LS | --- | --- | 1,200,000 |
| Plumbing | LS | --- | --- | 700,000 |
| Electrical | LS | --- | --- | 1,200,000 |
| Total | | | | $4,600,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

FUTURE CoF ESTIMATED FUNDING REQUIRED TO COMPLETE THIS PROJECT. None

GODDARD SPACE FLIGHT CENTER
FISCAL YEAR 1998 ESTIMATES
RESTORATION OF SPACE/TERRESTRIAL APPLICATION FACILITY

LOCATION PLAN

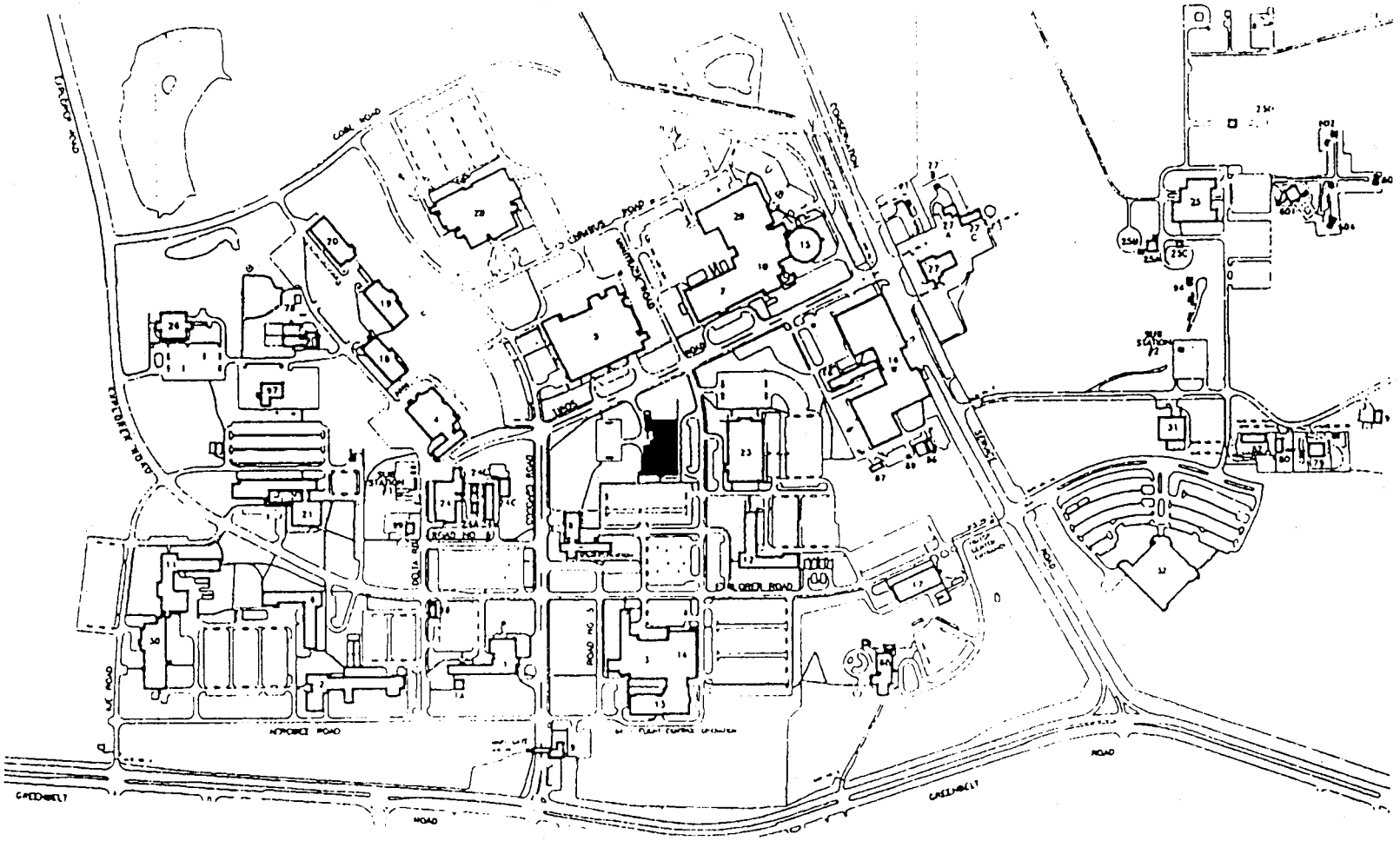

FIGURE 1

**PROJECT LOCATION**

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Construction of Emergency Services Facility

INSTALLATION: Jet Propulsion Laboratory

FY 1998 Estimate: $4,800,000

LOCATION OF PROJECT La Canada-Flintridge, Los Angeles County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Space Science

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project.

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $405.514 | --- | $405.514 |
| Capitalized Investment | --- | --- | --- |
| Total | $405.514 | --- | $405.514 |

SUMMARY PURPOSE AND SCOPE:

This project constructs a two-story building approximately 1700 square meters (SM) to accommodate Medical Services, Plant Security, Fire Department, and Emergency Preparedness Services. These services are currently housed in badly deteriorated facilities that will be demolished upon completion of this new project.

PROJECT JUSTIFICATION:

These essential services are housed in a combination of substandard buildings and trailers that are dispersed across the Jet Propulsion Laboratory. The existing facilities are too small, inefficient, and do not meet current seismic standards. The Fire Department operates 24 hours per day, with a hazardous materials response capability, and is serving over twice the population it was designed to handle. The security console at the Fire and Guard center of operations was designed to monitor 56 alarm stations. It now

handles 1,000 stations with plans to add another 3,000 stations. The equipment is now housed in a small, existing, wood-framed structure that is difficult to access, not adequately secured, and lacks proper air circulation for electronic equipment. An Emergency Operations Center is required to house combined fire and security operations. Some space will be used for classroom and training when available during normal operations. Medical services. including counseling, records maintenance, and administrative support have more than doubled to comply with increased testing requirements, employer responsibilities, and regulations. The counseling department is currently located in a trailer without a group meeting area, restroom facilities and sound-controlled counseling rooms.

IMPACT OF DELAY:

Failure to construct this Facility will result in continued operation in substandard facilities that are dispersed, unsafe, and not designed to accommodate the expanded emergency response capabilities and staffing. These facilities are unlikely to withstand a major earthquake, yet house the functions critical to JPLs ability to respond to this and other emergency situations. Existing facilities seriously degrade JPL's ability to perform these functions effectively.

PROJECT DESCRIPTION:

The project constructs a two-story concrete masonry unit, steel-frame, seismic-safe building of approximately 1,700 square meters (SM). It will be located on the north side of Explorer Road, east of Surveyor Road, on the site currently occupied by Buildings 72, 91, and 93 which will be demolished. Windows will have insulated bronze tinted glazing for solar and glare control. Interior spaces will be defined by metal stud and gypsum board partitions. Carpet will be installed in the medical services area, except in the emergency room and storage/utility areas and in the classroom/emergency operations area. Vinyl composition tile flooring will be installed in the fire and plant protection areas. Ceilings will be lay-in acoustical tile with recessed fluorescent lighting fixtures. The computer control room will have access flooring and indirect lighting.

The building will be air conditioned by an energy-efficient, variable-volume, heating and cooling system. The electrical system will include 480/277V power for lighting and 208/120V transformers providing power to receptacles. Other systems in the building will include telephone, fire detection/protection, energy management control system (EMCS), and institutional local area network (ILAN).

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Sitework | LS | --- | --- | $1,000,000 |
| Archectitural/Structural | LS | --- | --- | 2,500,000 |
| Mechanical | Ls | --- | --- | 800,000 |
| Electrical | Ls | --- | --- | 500.000 |
| Total | | | | $4.800.000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

# JET PROPULSION LABORATORY
# FISCAL YEAR 1998 ESTIMATES
# CONSTRUCTION OF EMERGENCY SERVICES FACILITY

## LOCATION PLAN

FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Upgrade of Utility Annex Chilled Water Plant

INSTALLATION: John F. Kennedy Space Center

FY 1998 Estimate: $5,900,000

LOCATION OF PROJECT: Kennedy Space Center, Brevard County, Cape Canaveral, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $600,000 | --- | $ 600,000 |
| Capitalized Investment | --- | $7,877,287 | 7,877,287 |
| Total | $600,000 | $7,877,287 | $8,477,287 |

SUMMARY PURPOSE AND SCOPE:

The central utility annex contains five outdated chillers with a total cooling capacity of 11,500 tons. This project will replace these chillers and upgrade the total cooling capacity of the plant to handle present day demand for chilled water.

PROJECT JUSTIFICATION:

The existing chillers are over 30 years old, experience increased unscheduled outages including a recent catastrophic failure, use the environmentally unacceptable refrigerant CFC-12, and are highly energy inefficient. Further, existing plant capacity is insufficient to support the cooling requirements of additional facilities scheduled to be connected to the chiller plant over the next three years.

IMPACT OF DELAY:

Failure to upgrade or replace deteriorated equipment continues the **risk** that unscheduled outages will increasingly interfere with KSC's ability to meet critical mission schedule milestones. Escalating maintenance and repair costs will increase continually, particularly as a result of the recent termination of production and importation of all CFC-12 refrigerant. Ongoing cooling operations will become marginal as additional facilities are connected and activated.

PROJECT DESCRIPTION:

This project upgrades or replaces the five chillers located in the north area utility annex, Building K6-947. It may prove economical to upgrade one or two of the five chillers to provide greater capacity, economy, and environmental compatibility. The remaining chillers cannot be economically revitalized and must be replaced.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Site & Civil | LS | --- | --- | $ 500,000 |
| Mechanical | LS | --- | --- | 4,400,000 |
| Electrical | LS | --- | --- | 1,000,000 |
| Total | | | | $5,900,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT None

# JOHN F. KENNEDY SPACE CENTER
# FISCAL YEAR 1998 ESTIMATES
# UPGRADE OF UTILITY ANNEX CHILLED WATER PLANT

## LOCATION PLAN

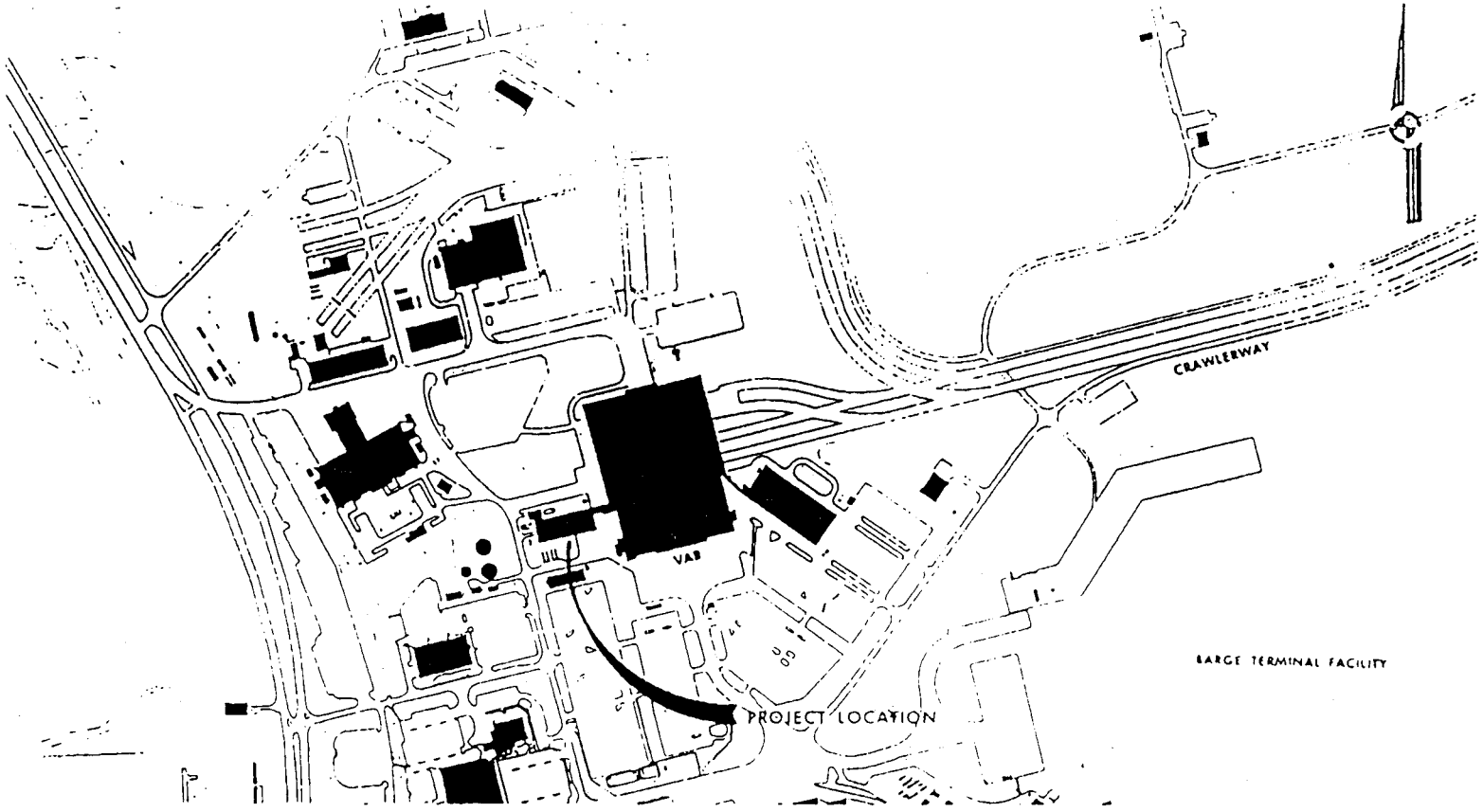


FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Rehabilitation of High Voltage Svstem

INSTALLATION: Lewis Research Center

FY 1998 ESTIMATE: $9.400.000

LOCATION OF PROJECT: Cleveland, Cuyahoga County, Ohio

COGNIZANT HEADQUARTERS OFFICE: Office of Aeronautics

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $1,890,000 | --- | $1,890,000 |
| Capitalized Investment | --- | $6,490,000 | 6,490,000 |
| Total | $1,890,000 | $6,490,000 | $8,380,000 |

SUMMARY PURPOSE AND SCOPE:

This project rehabilitates and modifies substations K, F, and G of the Center's High Voltage Power System. The project is required to assure continued reliable and safe electrical power supply at LeRC. The system distributes power to all of the Center's aerospace research and development facilities, computer center, and the institutional facilities. These facilities are required for Lewis Research Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

This system provides power to the major aeropropulsion and space simulation facilities. It is 50 years old, obsolete, and experiencing increased maintenance and emergency repairs each year. Current circuit breaker overloads and single point failures warn of a major failure that could result in a 6 to 12-month shutdown. Economic analysis indicates this project is the most cost-effective approach to maintain an operating system for the next 30 years.

IMPACT OF DELAY:

Unless the system is rehabilitated, failure rates currently being experienced are expected to increase. Major disruptions of electrical services, associated with single point failures, are also anticipated. These failures will result in the shutdown of critical research facilities and the programs they support for periods of up to 12 months.

PROJECT DESCRIPTION:

The work modifies the existing 138 kV Substation K, including new incoming 138 kV circuits, transformers, switching devices, and support structure and equipment. The work **also** rehabilitates and modifies existing 34.5 kV Substations F&G, including new circuits from Substation K, breakers, and transformers.

PROJECT COST ESTIMATE

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| 138 kV Substation Modifications | LS | --- | --- | $2,800,000 |
| 138 kV Circuits and Line Exits | LS | --- | --- | 1,200,000 |
| 34.5 kV Ties and Line Exits | LS | --- | --- | 2,400,000 |
| 34.5 kV Circuits and Equipment | LS | --- | --- | 3,000,000 |
| Total | | | | $9,400,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None. However, funding will be required in future years to rehabilitate other elements of the Electrical Distribution System.

LEWIS RESEARCH CENTER
FISCAL YEAR 1998 ESTIMATES
REHABILITATION OF HIGH VOLTAGE SYSTEM

LOCATION PLAN

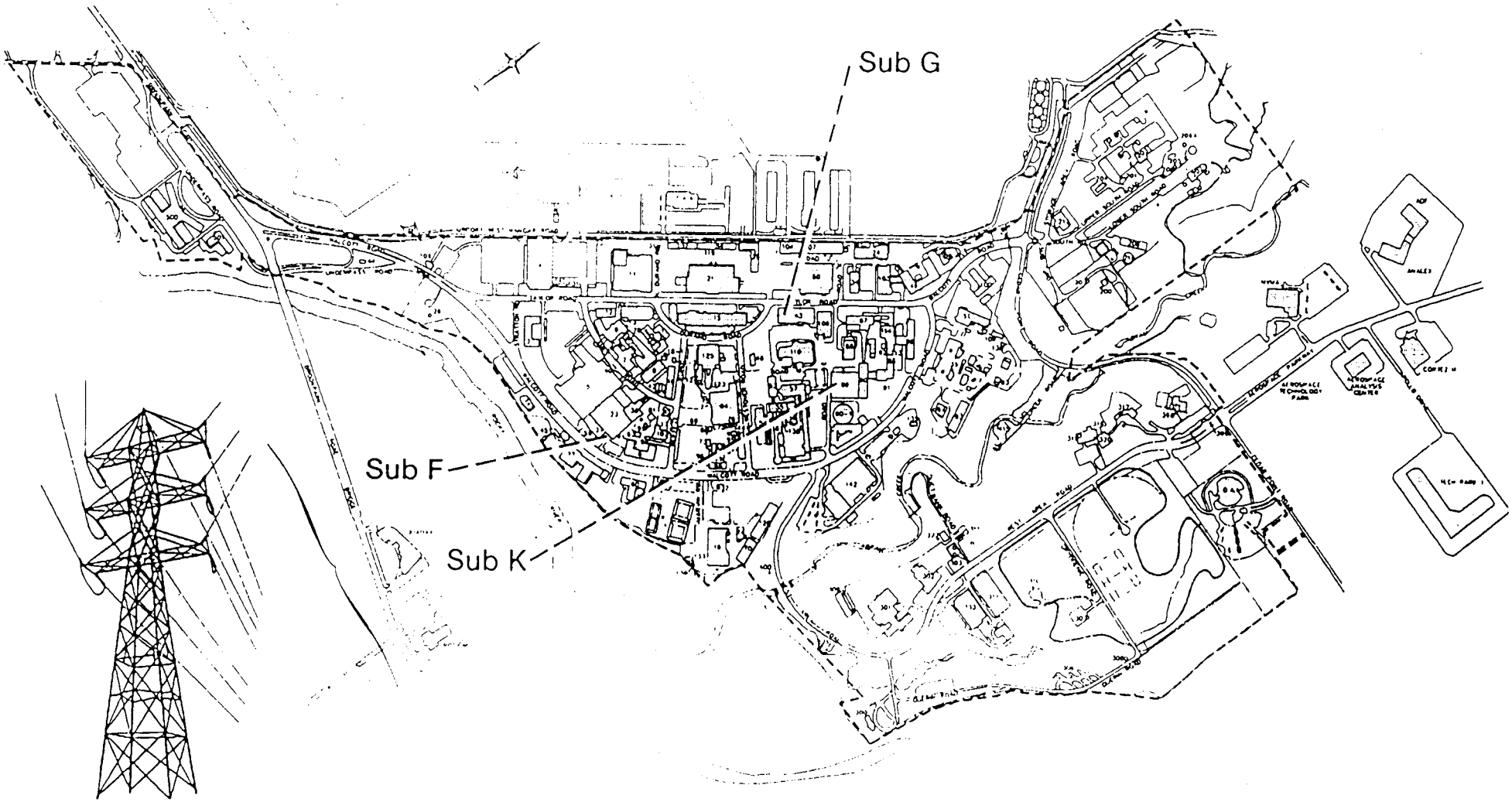


FIGURE 1

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

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PROJECT TITLE: Modification of Chilled Water System

INSTALLATION: George C. Marshall Space Flight Center

FY 1998 Estimate: $7,000,000

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LOCATION OF PROJECT Marshall Space Flight Center, Madison County, Alabama

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1997 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

| | Planning and Design | Construction | Total |
|---|---|---|---|
| Specific Construction Funding | $1,574,463 | $6,700,000 | $8,274,463 |
| Capitalized Investment | -- | -- | -- |
| Total | $1,574,463 | $6,700,000 | $8,274,463 |

SUMMARY PURPOSE AND SCOPE:

This project expands the central chiller plant and chilled water distribution system approved by Congress for construction in FY 1997 to additional areas of the Center. It converts the chilled water system from individual chiller units to a central chiller plant with a chilled water (pipeline) distribution system. The project will significantly reduce operations, maintenance, and energy costs: improve reliability in support of critical operations; and help phase out the use of existing refrigerants which are no longer in production. The chilled water system supports facilities required for Marshall Space Flight Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:

The Center presently air conditions its facilities and equipment with chilled water produced by individual chillers in each building. These chillers are often backed up with a spare chiller due to redundancy requirements. Consolidating service out of a central chiller plant reduces the total capacity required and the overall cost involved in providing the same level of redundancy. This project also avoids a huge maintenance and repair backlog. Existing chillers affected by this project are old, unreliable, and use refrigerants which are no longer in production. New chillers compatible with the new refrigerants require chiller equipment rooms to be extensively modified, and sometimes relocated, due to the toxic nature of the new refrigerants. Expanding the central chiller plant and distribution system to extend service to additional building areas with abundant individual units will eliminate disruptions associated with piecemeal repairs and will pay for itself in seven to eight years.

IMPACT OF DELAY

Failure of the existing chillers results in downtimes for extensive repairs that are disruptive to the operation of the Center and which require costly work arounds such as leasing of emergency chillers. Chillers will continue to be replaced individually which is an inefficient financial investment. Failure to convert to the new refrigerants will also require accumulation and stockpiling of the old refrigerant at continually escalating, premium prices.

PROJECT DESCRIPTION:

This project expands the central chiller plant and chilled water distribution system approved by Congress for construction in FY 1997. Scope includes the acquisition and installation of additional cooling tower cells, chillers, and associated mechanical and electrical equipment to extend service to additional areas. Due to technical considerations which surfaced during design, the scope of the FY 1997 project was adjusted to provide service to portions of the 4400 area instead of the 4200 area. This project will extend the 4400 loop to capture additional buildings in that area and constructs the loop that will provide service to most of the 4200 area.

PROJECT COST ESTIMATE:

| | Unit of Measure | Quantity | Unit Cost | Cost |
|---|---|---|---|---|
| Mechanical | Ls | --- | --- | $4,000,000 |
| Electrical | Ls | --- | --- | 1,000,000 |
| Distribution System and Hook-up | Ls | --- | --- | 2,000,000 |
| Total | | | | $7,000,000 |

LIST OF RELATED GRAPHICS: Figure 1 - Location Plan

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT Future CoF funding in the range of $7,500,000 to $9,000,000 is planned in FY 1999 to expand the Central Chiller Plant services to other areas of the Center.

MARSHALL SPACE FLIGHT CENTER
FISCAL YEAR 1998 ESTIMATES
MODIFICATION OF CHILLED WATER SYSTEM

LOCATION PLAN

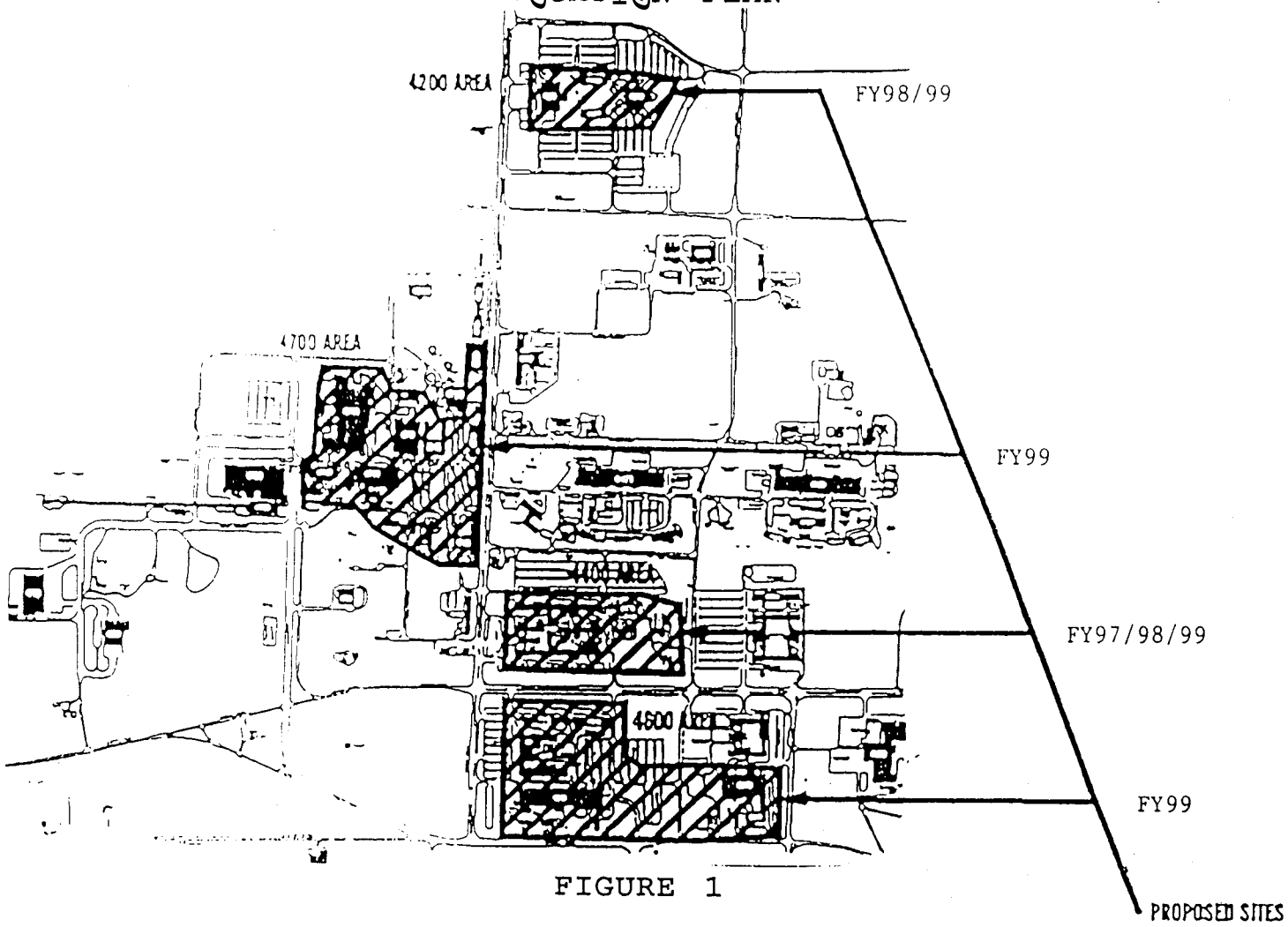


FIGURE 1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

SUMMARY

MINOR REVITALIZATION

| Summary of Project Amounts by Location: | Repair | Rehabilitation & Modification | Total Revitalization |
|---|---|---|---|
| Ames Research Center . . . . . | $2.850.000 | $2.100.000 | $ 4,950.000 |
| Dryden Flight Research Center . . . . . | 1.350.000 | 1.550.000 | 2.900.000 |
| Goddard Space Flight Center . . . . . | 3.450.000 | 2.670.000 | 6.120.000 |
| Jet Propulsion Laboratory . . . . . | 3.050.000 | 3.950.000 | 7.000.000 |
| Johnson Space Center . . . . . | 3.000.000 | 600.000 | 3.600.000 |
| Kennedy Space Center . . . . . | 4.210.000 | 3.290.000 | 7.500.000 |
| Langley Research Center . . . . . | 3.485.000 | 1.715.000 | 5.200.000 |
| Lewis Research Center . . . . . | 1.800.000 | 3.050.000 | 4.850.000 |
| Marshall Space Flight Center . . . . . | 2.150.000 | 4.540.000 | 6.690.000 |
| Michoud Assembly Facility . . . . . | 3.450.000 | 2.610.000 | 6.060.000 |
| Stennis Space Center . . . . . | 2.000.000 | 1.800.000 | 3.800.000 |
| Wallops Flight Facility . . . . . | 1.800.000 | 2.330.000 | 4.130.000 |
| Various Locations . . . . . | - 0 - | 2.900.000 | 2,900.000 |
| Total . . . . . | $32.595.000 | $33.105.000 | $65.700.000 |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Minor Revitalization of Facilities. Not in Excess of $1,500.000 Per Proiect

INSTALLATION: Various Locations

FY 1998 Estimate: $65.700.000

FY 1996: $70,000,000 FY 1997: $57,900,000

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Management Systems and Facilities

SUMMARY PURPOSE AND SCOPE:

These resources provide for revitalization of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. The request includes facility revitalization needs for FY 1998 that can be identified at the time of the submission of these estimates that are not in excess of $1.5 million per project. The revitalization program has two components, repair projects and rehabilitation and modification projects. Repair projects restore facilities and components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. Repair work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown and major preventive measures that are normally accomplished on a cyclic schedule. Rehabilitation and modification projects may include some restoration of current functional capability but also includes enhancement of the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability. The facilities being revitalized in this program are expected to remain active in the long term and are consistent with current and anticipated Agency roles and missions.

PROJECT JUSTIFICATION:

NASA is now experiencing "block obsolescence" where a substantial portion of the agency's facilities have been in use for over **30** 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 in the interest of long-term economy. 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. Approximately 90 percent of NASA's physical plant has been in service for over 25 years.

The NASA physical plant has a capital investment of $5.9 billion and has a current replacement value of more than $17 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. Avoid significantly greater future repair costs.

This program includes only facility revitalization work of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance and repair activities, Projects estimated to cost more than $1.5 million are included as separate discrete projects in the budget request.

PROJECT DESCRIPTION:

Proposed projects for FY 1998 totaling $65.7 million are identified on the following four pages. 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 $65.7 million includes repair projects totaling $32.6 million and rehabilitation and modification projects totaling **$33.1** million.

During the course of 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 available revitalization resources. The following broad categories of work are included within the repair and the modification and rehabilitation projects identified on the following six pages.

| | |
|---|---|
| a. Utility Systems | $18,400,000 |
| b. General Purpose Buildings | 8,795,000 |
| c. Technical Buildings/Structures | 25.3 15,000 |
| d. Pavements and Drainage | 940,000 |
| e. Building Exteriors and Roofs | 5,730,000 |
| f. Fire Detection/Protection Systems | 6,520,000 |

PROJECT COST ESTIMATE:

**I. REPAIR**

| | |
|---|---|
| A. Ames Research Center (ARC) | $2,850,000 |
| 1. Repair Natural Gas Distribution System | 500.000 |
| 2. Repair Vane Sets 6 and 7. National Full-Scale Aerodynamics Complex (N-221) | 850.000 |
| 3. Repair Pressure Systems | 600.000 |
| 4. Repair Building (N-215) | 900.000 |
| B. Drvden Flight Research Center (DFRC) | $1.350. 000 |
| 1. Repair Heating. Ventilation and Air Conditioning Systems. Various Buildings | 950.000 |
| 2. Repair Roofs. Various Buildings | 400.000 |
| C. Goddard Space Flight Center (GSFC) | $3.450.000 |
| 1. Repair Roofs. Buildings 1 and 16W | 700.000 |
| 2. Repair Electrical Systems. Various Buildings | 800.000 |
| 3. Repair Exterior Walls. Building 3 | 800.000 |
| 4. Repair Steam Distribution System | 800.000 |
| 5. Repair Building Exteriors and Foundations. Various Buildings | 350.000 |
| D. Jet Propulsion Laboratorv (JPL) | $3.050.000 |
| 1. Replace Elevator. Building 198 | 630.000 |
| 2. Repair Heating Ventilating and Air Conditioning (HVAC) Controls. Building 264 | 620.000 |
| 3. Replace 'X Emergency Generator. Building 230 | 1,000.000 |
| 4. Repair Roofs. Various Buildings | 800.000 |
| E. Johnson Space Center (JSC) | $3,000,000 |
| 1. Repair 12.5KV Feeder Cables (2-8& 1-11) | 350.000 |
| 2. Repair Mechanical Systems (17) | 850.000 |
| 3. Replace 300 Area High Voltage Lines | 300.000 |
| 4. Repair Water and Steam Systems. Various Buildings | 900.000 |
| 5. Repair Electrical Equipment. Various Buildings | 600.000 |

| | |
|---|---|
| F. Kennedy Space Center (KSC) | $4,210,000 |
| 1. Refurbish Elevator Controls, Pads A & B | 600,000 |
| 2. Replace Chilled Water System, Vertical Processing Facility | 750,000 |
| 3. Replace Potable Water Piping & Firex System, Vertical Assembly Building | 1,300,000 |
| 4. Repair Elevator Controls, Vertical Assembly Building, High Bays 1 & 3 | 1,100,000 |
| 5. Restore Visual Landing Aid System | 460,000 |
| G. Langley Research Center (LaRC) | $3,485,000 |
| 1. Replace Power Supply, Arc-Heated Scramjet Test Facility, (1247B) | 1,400,000 |
| 2. Replacement of Substation Serving Building 1244 | 810,000 |
| 3. Repair Roof, 1268A | 400,000 |
| 4. Replace Settling Chamber, 20-Inch Mach 6 Tunnel, (1247D) | 875.000 |
| H. Lewis Research Center (LeRC) | $1,800,000 |
| 1. Repair South Chilled Water Distribution Piping | 900,000 |
| 2. Repair Chiller #2, Refrigeration Building (9) | 900,000 |
| I. Marshall Space Flight Center (MSFC) | $2,150,000 |
| 1. Repair Roof of High Bay Building (4755) | 950,000 |
| 2. Repair Electrical and Mechanical Systems (4619) | 1,200,000 |
| J. Michoud Assembly Facility (MAF) | $3,450,000 |
| 1. Repair LN2/GN2 Steam Boilers (175) | 800.000 |
| 2. Repair Chilled Water Pumps (103/160) | 950,000 |
| 3. Repair Manufacturing Area Fanhouses (103) | 900,000 |
| 4. Repair Natural Gas System, Site Wide | 800,000 |
| K. Stennis Space Center (SSC) | $2,000,000 |
| 1. Repairs to High Pressure Gas Piping | 600.000 |
| 2. Repair 13.8KV Selector Switches and Substations | 500.000 |
| 3. Repair Motor Control Centers and 480 Volt Electrical Distribution Systems, Various Facilities | 900,000 |

| | |
|---|---|
| L. Wallops Flight Facility (WFF) | $1,800,000 |
| 1. Repair of Roofs, Various Buildings | 400,000 |
| 2. Repair of Various Communication Towers | 500.000 |
| 3. Repair of Storm Drainage System | 500,000 |
| 4. Repair of Elevated Water Tank (X-45) | 400,000 |
| **Total Repair** | **$32,595,000** |

FUTURE ESTIMA CONSTRUCTION F INDING REQUIRED:

Approximately $30-$40 million per year will be required for continuing repair needs.

## 11. REHABILITATION AND MODIFICATION

| | |
|---|---|
| A. Ames Research Center (ARC) | $2,100,000 |
| 1. Rehabilitate and Modify Fire Suppression System, N240/N240A | 250,000 |
| 2. Rehabilitate and Modify Bridge Crane, N227D | 350.000 |
| 3. Rehabilitate and Modify 60 Mega Watt (MW) DC Power Supply, N238 | 750,000 |
| 4. Modify Compressor Controls for Building N229A | 750.000 |
| B. Drvden Flight Research Center (DFRC) | $1.550.000 |
| 1. Rehabilitate and Modify Fire Alarm Systems, Various Locations | 950,000 |
| 2. Rehabilitate Warehouses. Various Locations | 600,000 |
| C. Goddard Space Flight Center (GSFC) | $2,670,000 |
| 1. Rehabilitation of Utility Control System | 900,000 |
| 2. Rehabilitation of Heating Ventilating, Air conditioning (HVAC) System and Controls, Building 21 | 500,000 |
| 3. Rehabilitation and Modification of Laboratory Areas in Building 5 and 22 | 550,000 |
| 4. Modification of TV Facility, Building 3/14 | 720.000 |
| D. Jet Propulsion Laboratorv (JPL) | $3.950.000 |
| 1 Modify Administration Building, Building 180 | 1,400,000 |
| 2. Modify Facility Power System, Building 150 | 550,000 |
| 3. Modify Fire Alarm Systems, Various Buildings | 1,250,000 |
| 4. Modify Photographic Laboratory, Building 111 . | 750,000 |
| E. Johnson Space Center (JSC) | $600,000 |
| 1. Rehabilitate/Modify Building 7 | 600,000 |
| F. Kennedv Space Center (KSC) | $3,290,000 |
| 1. Modify Access Safety Devices, LC-39 Area | 750.000 |
| 2. Modify Base Support Facilities Fire Protection System (M6-486) | 800,000 |
| 3. Modify Mobile Launch Platforms HVAC Equipment | 800,000 |
| 4. Upgrade Two Schwartz Road Intersections | 440,000 |
| 5. Upgrade Facilities for People with Disabilities, Various Locations | 500.000 |

| | |
|---|---|
| G. Langlev Research Center (LaRC) | $1.715.000 |
| 1. Modifications to Unitary Plan Wind Tunnel Control System, Building 1251 | 1,000,000 |
| 2. Modifications for Disabled Accessibility, Various Facilities, Phase II | 715,000 |
| H. Lewis Research Center (LeRC) | $3,050,000 |
| 1. Rehabilitation of Mechanical and Electrical Systems in Chemistry Laboratory (6) | 950,000 |
| 2. Rehabilitation of Mechanical and Electrical Systems in 8x6 Supersonic Wind Tunnel Office (54) | 950,000 |
| 3. Rehabilitation of Mechanical and Electrical System, Materials Processing Lab (MPL) (105) Phase 2 | 850,000 |
| 4. Modification to Heating, Ventilation and Air Conditioning (HVAC) in Model Shop (50) | 300,000 |
| I. Marshall Space Flight Center (MSFC) | $4.540.000 |
| 1. Fire Protection and Electrical Modifications to Office Building (4200) | 970,000 |
| 2. Rehabilitate Heat Treatment Facility (4704) | 800,000 |
| 3. Modifications for Hydraulic and Electro-Mechanical Actuator Laboratory (4656) | 520,000 |
| 4. Restoration of Multi-Purpose High Bay Facility (4649) | 1,300,000 |
| 5. Rehabilitation of Components Service Building (4653) | 950,000 |
| J. Michoud Assemblv Facilitv (MAF) | $2.610.000 |
| 1. Rehabilitate and Modify Chilled Water System (207/320) | 910,000 |
| 2. Rehabilitate and Modify Central Plant Air System | 800,000 |
| 3. Rehabilitate and Modify Central Fire Water Mains (318/400 area) | 900,000 |
| K. Stennis Space Center (SSC) | $1,800,000 |
| 1. Modify Energy Management Control Systems | 900,000 |
| 2. Rehabilitate and Modify 4.16KV Switchgear and Controls [B-4400] | 900,000 |
| L. Wallops Flight Facilitv (WFF) | $2,330,000 |
| 1. Rehabilitation of Telemetry Receiving and Recording Facility, Building N-162 | 900,000 |
| 2. Rehabilitation of Assembly Shop, Building W-65 | 580,000 |
| 3. Modification of Causeway Bridge | 400,000 |
| 4. Modification of Heating, Ventilating, and Air Conditioning Systems (HVAC), Systems, Various Buildings | 450,000 |

| | |
|---|---|
| M. Various Locations | $2.900.000 |
| 1. Modifications to DSS-27 & 28, Goldstone, California | 900.000 |
| 2. Modification of Power Distribution, Madrid, Spain | 600,000 |
| 3. Modify Chilled Water System, DSS-14, Goldstone, California | 700,000 |
| 4. Modify Chilled Water System, Canberra, Australia | 700.000 |
| **Total Rehabilitation and Modification** | **$33.105.000** |

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED:
Approximately $30-40 million per year will be required for continuing rehabilitation and modification needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

SUMMARY

MINOR CONSTRUCTION

| Summary of Project Amounts by Location: | Amount |
|---|---|
| Langley Research Center | 700,000 |
| Lewis Research Center | 400,000 |
| Total | $1,100,000 |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Minor Construction of New Facilities and Additions to Existing Facilities Not in Excess of $1,500,000 Per Proiect

INSTALIATION: Various Locations

FY 1998 Estimate: $1,100,000

| FY 1996: $3,800,000 | FY 1997: $3,400,000 |
|---|---|

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Officeof Management Systems and Facilities

SUMMARY PURPOSE AND SCOPE:

These resources will provide for minor facility construction at NASA field Installations. Each project in this program is estimated to cost no more than $1.5 million and involves either the construction of new facilities or additions to existing facilities. The FY 1998 request of $1.6 million will improve the usefulness of NASA's physical plant by changing the utilization of or augmenting the capabilities of various facilities. Included in this request are those programmatic and institutional projects that are essential to the accomplishment of mission objectives.

PROJECT JUSTIFICATION:

The configuration of NASA's physical plant necessarily must respond to changes in utilization and adaptions required by changes in technology or in mission needs. Demands are generated by research, development, testing, and similar activities.

PROJECT DESCRIPTION:

Included in the FY 1998 minor construction program are those facility projects for institutional or technical facility needs that could be fully identified at the time of submission of this budget estimate. Items of work totaling $1.1 million are included in this resource request. Projects were selected on the basis of the relative urgency of each item and the expected return on the investment. During the course of the year, the revision of priorities may require changes in some of the items to be accomplished. Such changes will be accommodated within the total resources allocated.

These projects represent requirements that must be met in this time frame to support institutional needs and programmatic objectives. They are in the Technical Buildings/Structures" category of work.

PROJECT COST ESTIMATE:

| | |
|---|---|
| **A.** Langlev Research Center (LaRC) | $700.000 |
| 1. Construction of Polymer Film Laboratory (1293C) | 700,000 |
| B. Lewis Research Center (LeRC) | $400.000 |
| 1. Construction **of** Build-up Area at Engine Components Research Laboratory (ECRL - 102) | 400,000 |
| **Total** | **$1.100.000** |

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED: Approximately $4-5 million per year will be required for continuing minor construction needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

SUMMARY

FACILITY PLANNING AND DESIGN

| | Amount |
|---|---|
| Master Planning | $ 400,000 |
| Sustaining Engineering Support | 9,000,000 |
| Preliminary Engineering Reports and Related Special Engineering Support | 1,600,000 |
| Final Design | 8,000,000 |
| Total | $19,000,000 |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Facility Planning and Design

FY 1998 Estimate: $19,000.000

FY 1996: $10,000,000 FY 1997: $18,700,000

The funds requested in this estimate are required to provide for the following advance planning and design activities related to facilities activities and projects where not otherwise provided for:

a. The accomplishment of necessary studies, development and master planning for field installation and the provision of continuing engineering support and special engineering management and other services.

b. The preparation of preliminary engineering reports, cost .estimates, and design and construction schedules. Also includes the preliminary engineering efforts required to initiate design-build projects.

c. The preparation of final designs which include construction plans, specifications, and associated cost estimates and schedules required to implement construction projects.

d. The accomplishment of facilities siting and other investigations, studies and reports.

**A. Master Planning** **$400,000**

Provides for updating, developing and automating existing field installation master plans. This effort includes facility studies, site investigations, and analyses of utility systems. The existing utility and civil drawings will be converted into a highly detailed electronic database using a computer-aided-design (CAD)system. Topographical features from original drawings will be merged electronically to create individual area maps or an entire center map. The master plan documents will be updated to reflect as-built conditions and to graphically represent the 5-year facility plan baseline for future development.

The NASA field center master plans are 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** **$9,000,000**

Provisions for facility studies and specific engineering support continue in importance as evidenced in recent years. These efforts are important due to changing cost trends in construction materials and fuels: the operation and maintenance costs for the physical plant: and energy conservation and efficiency.

The following items are included in the FY 1998 requirements:

1. Facilities Engineering Design and Construction Management Studies

This effort involves extremely high leverage facility studies and that are critically important to improve the quality and cost effectiveness of NASA's construction practices and to ensure that developing technology and industry best practices are incorporated into the agency's construction program.

2. Value Engineering, Cost Validations and Analyses

Provides for engineering services to improve cost-effectiveness of facility projects by subjecting project design criteria, specifications and working drawings for specific material components and systems to detailed independent reviews by engineering specialists. Also provides services necessary to predict and validate facility costs to aid in resources planning.

3. Facility Operation and Maintenance

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.

NASA's facilities infrastructure is critical to achieving current and future space and aeronautics program objectives. Two initiatives begun in FY 1996 and planned to conclude in FY 1998 keep this infrastructure safe, reliable, and available by substantially increasing the rate of return on severely constrained Agency facilities maintenance resources. These initiatives are:

a. Conversion to Reliability Centered Maintenance ($5million) - Provides for the change from a time driven and reactive/breakdown mode of maintenance to a more proactive program of Reliability Centered Maintenance (RCM). This program will focus on implementing the optimal mix of preventive, predictive, proactive, and reactive technologies which yields the required reliability at the minimum cost. It **also** aims to utilize system performance feedback to design potential failures out of systems. This agency-wide effort will include a detailed assessment of specific RCM opportunities and available Predictive Testing and Inspection (PT&I) technologies, the establishment of RCM processes and procedures, the establishment of responsible RCM organizations, and the acquisition of required PT&I monitoring equipment and training. This conversion to RCM will significantly reduce maintenance

cost by minimizing and/or eliminating time driven shutdowns and future breakdown maintenance. This provides the additional resources needed to implement this program, as **NASA** installations must still perform the current time-driven/breakdown maintenance in order to provide adequate mission support until the conversion is made. It is anticipated that this conversion will lead to an annual savings of $12 million in maintenance costs within three years and thereby ameliorate the negative impact of continuing low budget levels on the facilities infrastructure.

b. Conversion to Performance-Based Maintenance Contracting ($3million) - Provides for the change from "umbrella" cost reimbursement contracts to performance-based, fixed-price contracts for facilities maintenance, repair, and operations contracts. Currently about 90 percent of NASA contracts for these services are cost reimbursement contracts. It is estimated that from $35 to $50 million per year can be saved by successfully converting these contracts to performance-based, fixed-price contracts. This will also lessen the impact of low future budgets. This provides for the substantial up-front effort required to collect and analyze the required data, prepare performance-based specifications that fully support mission urgency and timeliness, tailor and implement comprehensive quality assurance programs, and train personnel.

4. Facilities Utilization Analyses

Provides for the analyses of agencywide facilities utilization data covering (1)office and other types of building space: (2)designate 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 facilities to meet Agency physical plant reduction objectives. Work provides for review of each installation's inventory data base in support of the facilities utilization program. Surveys are necessary to validate the reported data in relation to a specific problem or need, and to assist in providing a credible foundation for plans to improve the use of facilities.

5. 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.

6. Independent Analysis and Third Party Reviews

Provides the technical and engineering support analyses, designs, and reviews required to verify, confirm and ensure suitability of construction designs within the project cost estimates.

7. Construction Industries Institute

Covers annual support to the Construction Industries Institute (CII). **NASA** actively participates in this unique, non-profit institution, established to bring together major facility owners, contractors and academia in a proven effort to improve the quality and cost effectiveness of construction management practices for member organizations as well as the US construction industry.

8. National Research Council

Covers annual support to the Federal Facilities Council's (FFC) operations and provides for special studies that the Council will perform throughout FY 1998 to help advance the science and technology of Federal Government building and construction. The FFC is subordinate to the National Research Council, National Academy of Sciences, and its activities are supported by NASA and other Federal agencies with similar construction programs.

**C. Preliminary Engineering Reports and Related Special Engineering Support** ..... **$1,600,000**

**1. Preliminary Engineering Reports (PERs)** ..... **(1,200,000)**

This estimate provides for preparation of PERs, investigations, and project studies related to proposed facility projects in the FY 2000 and FY 2001 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. This request provides for PERs associated with proposed construction.

**2. Related Special Engineering Support** ..... **(400,000)**

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 like studies. These studies are required to allow for the timely development of projects to meet the stated functional needs and to provide basic data, cost estimates and schedules for related future budgetary proposals.

**D. Final Desi..** ..... **$8,000,000**

The amount requested will provide for the preparation of designs, plans, drawings, and specifications necessary for the accomplishment of projects. Projects involved are planned for inclusion in the FY 1999 and FY 2000 programs. The goal is to obtain better facilities on line earlier at a lower cost. The request will provide for final design work associated with construction proposed for the FY 1999 program, estimated to cost $1 10 to $130 million, and for $20 to $30 million of high potential projects proposed for the FY 2000 program.

**Total.** ..... **$19,000,000**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

SUMMARY

ENVIRONMENTAL 1PLIA AND RESTORATION

| Summarv of Proiect Amounts **bv** Location: | Amount |
|---|---|
| Ames Research Center | $ 600,000 |
| Dryden Flight Research Center | 700,000 |
| Goddard Space Flight Center | 500,000 |
| Jet Propulsion Laboratory | 2,750,000 |
| Johnson Space Center | 550,000 |
| Kennedy Space Center | 4,680,000 |
| Lewis Research Center | 3,150,000 |
| Marshall Space Flight Center | 3,000,000 |
| Michoud Assembly Facility | 2,000,000 |
| Stennis Space Center | 3,700,000 |
| Wallops Flight Facility | 300,000 |
| White Sands Test Facility | 2,800,000 |
| Various Locations | 285,000 |
| Miscellaneous Projects Not in Excess of $250,000 Each | 245,000 |
| Remedial Investigations, Feasibility Studies, Assessments, Studies, Design, and Related Engineering | 8,740,000 |
| Total | $34,000,000 |

CONSTRUCTION OF FACILITIES

FISCAL YEAR 1998 ESTIMATES

PROJECT TITLE: Environmental Compliance and Restoration Program

INSTALIATION: Various Locations

FY 1998 Estimate: $34,000,000

FY 1996: $37,000,000 FY 1997: $33,000,000

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Management Systems and Facilities

SUMMARY PURPOSE AND SCOPE:

These resources will provide for environmental studies, assessments, investigations, designs, related engineering, and remedial action and construction projects for environmental compliance and restoration measures at NASA field installations, Government-owned industrial plants supporting NASA activities, and other locations 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 and assessments in support of functional leadership initiatives related to environmental compliance and restoration activities. The purpose of this program is to enable NASA to comply with environmental statutory and regulatory requirements and standards, cleanup orders, and regulatory agreements. The resources authorized and appropriated pursuant to this program may not be applied to other activities. The program includes studies or assessments to determine compliance status and options for remedial actions, including evaluations and use of new cleanup technologies, and to support environmental initiatives; conduct of prescribed remedial investigations and feasibility studies as required by environmental laws and regulations: performance of environmental restoration, hazardous waste removal and disposal, cleanups, and closures: and environmental compliance activities.

PROJECT JUSTIFICATION/DESCRIPTION:

Proposed environmental compliance and restoration projects and activities for Fiscal Year 1998 total $34.0 million. This program represents this year's request on a phased approach in relation to the total requirements for environmental restoration that must be

implemented within the next several years. Based on relative urgency and potential health hazards, the following listed projects are the highest priority requirements currently planned for accomplishment in FY 1998. Deferral of these necessary compliance and remedial measures would preclude NASA from complying with environmental requirements and regulatory agreements, and jeopardize critical NASA operations. The studies, remedial investigations, feasibility studies, assessments, design, and related engineering costs are estimated to be approximately $8,740,000. Projects estimated to cost less than $250,000 have not been described or identified by specific location. The estimated costs of these projects is $245.000. As studies, assessments, remedial investigations, feasibility studies, and designs progress and as new discoveries or regulatory requirements change, it is expected that priorities may change and revisions of the activities and projects may be necessary.

The following listing summarizes broad categories of effort to be undertaken with the identified estimated costs over $250,000:

| | |
|---|---|
| a. Hazardous Waste Corrective Actions/Cleanups | $22,930,000 |
| b. Hazardous Waste/Material Storage and Control | 950,000 |
| c. Water Pollution Control | 1,135,000 |

PROJECT COST ESTIMATE:

A. Ames Research Center (ARC) $600,000

1. Remediate Soil Contamination at Area of Investigation No. 10 . 600,000

The project will provide for the removal or in-situ treatment and containment of PCB and oil contaminated soil around the electrical substations that make up Area of Investigation No. 10 at Ames. Initial sampling of the areas have revealed contamination around the transformer pads. Cleanup of the sites is required by the Toxic Substances Control Act (TSCA) and the State of California Department of Toxic Substances Control.

B. Drvden Flight Research Center (DFRC) $700,000

1. Remediation of Soil/Groundwater Contamination 700,000

This project continues the efforts and activities to characterize and remediate site contamination at DFRC. The Center is identified as Operable Unit No. 6 (OU #6) under the Edwards Air Force Base (EAFB) Superfund Program. The project will provide for follow-on phases to investigation activities including risk assessments, feasibility and treatability studies, and proposed remedial plans and reports required to address all sites of concern under OU #6. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) program for OU #6 is conducted in coordination with the Accelerated Site Cleanup process being implemented at the EAFB. This work is required by CERCLA and is subject to the provisions of the EAFB Federal Facilities Agreement.

C. Goddard Space Flight Center (GSFC) $500,000

1. Remediation of Contaminated Sites 500,000

This project continues the efforts to investigate, characterize and remediate identified contaminated sites, including three abandoned landfills and other sites at GSFC. The work follows-on to the site investigations previously conducted which identified the presence of contamination at these sites. The project is required to bring the facility into compliance with CERCLA/Resources Conservation and Recovery Act (RCRA) and state requirements.

D. Jet Propulsion Laboratorv (JPL) . $2,750,000

1. Remediation of Arroyo Seco Groundwater Contamination 1,750,000

This project continues the cleanup effort of the Arroyo Seco aquifer contamination. Site investigations have demonstrated the presence of contaminants beneath the site and in nearby production wells in excess of federal and State of California standards. This portion of the project provides for follow-on actions to site investigations and characterization and site risk assessments. It provides for

treatability studies to evaluate and determine appropriate technologies for remedial actions, and project activities to reach decisions on the level and extent of site cleanup. It also provides for interim removal actions for soil and groundwater remediation. The work is being conducted following the federal EPA, state and local requirements. The project also provides for payment of oversight costs as required under the Federal Facilities Agreement (FFA).The site is listed in the Environmental Protection Agency's (EPA) National Priorities List and is subject to the provisions of CERCLA.

2. Environmental Assessment and Cleanup, Edwards Test Facility (ETF) . . . . . 1,000.000

This project continues the effort to investigate, characterize, and cleanup site contamination as required for closure of the ETF. The Facility is a tenant of Edwards Air Force Base (EAFB)and is identified as Operable Unit No. 5 under the EAFB Superfund site. This portion continues ongoing work including site characterization and risk assessments, in addition to providing for treatability studies and the evaluation, testing, and implementation of remedial actions for site cleanup. This work is required as part of the CERCLA cleanup process.

E. Johnson Space Center (JSC) *$550.000*

1. Closure of Impoundments (358) 250,000

The project will provide for the proper closure of two surface impoundments located near Building 358, around the Hazardous Waste Facility area. The 500,000 and 25,000 gal surface impoundments provided containment for the hypergolic fuels no longer in use at the facility. Closure of the impoundments will reduce the possibility for misuse of the impoundments for the storage of hazardous substances or wastes, thus preventing noncompliances with the Resource Conservation and Recovery Act (RCRA) as well as with spill and discharge requirements under the Clean Water Act (CWA).The project activities will conform with applicable closure requirements under RCRA.

2. Environmental Assessment/Cleanup for NASA Industrial Plant, Downey 300,000

This project continues site assessments and investigations to determine NASA's environmental responsibility prior to excessing some areas of the facility. The project will conduct area site characterizations to identify the extent of remedial actions, as well as provide information on other related environmental activities needed for transfer of property.

F. Kennedv Space Center (KSC) $4,680,000

1. Abandoned Tank Remediation 780,000

This project provides for follow-on actions to site investigations and characterization of underground storage tank (UST)sites. The USTs at these areas have been removed, but site assessments have identified petroleum contamination in the soils and groundwater as a result of previous UST system operations. The project will provide for remediation and proper closure of the sites, to conform with the federal, state and local UST requirements.

2. Closure of Ramson Road Landfill 1,100,000

This project provides for additional work required to properly close the Ramson Road Landfill, to include site remediation and provisions for installation of site monitoring equipment, as required for the closure. Site investigations have identified groundwater contamination above regulatory standards. The landfill closure is mandated under a State of Florida issued consent order, and under an existing permit issued by the EPA. The site has been identified to EPA as a Solid Waste Management Unit under RCRA.

3. Remediation of Components Cleaning Facility (CCF) Laboratory *2,000,000*

This project provides for follow-on actions to site investigations and characterization of the CCF area, to provide for site remediation and corrective action activities. Site investigations have identified contaminants in soil and groundwater. Cleanup of the site is required under an existing permit issued by the EPA. This work will be in conformance with RCRA requirements.

4. Remediation of Spaceport USA, Diesel Fuel Storage Area *800,000*

This project provides for site remediation of fuel contaminants in the area groundwater. This work follows the site investigations and characterization of the area, and initiates the implementation of remedial actions currently under negotiations to cleanup the site. The project follows requirements under the federal, state and local standards.

G. Lewis Research Center (LeRC) $3,150,000

1. Remediation of Contaminated Sites, Cleveland *2,500,000*

This project continues the effort to investigate, characterize, and remediate site contamination for identified contaminated areas within Lewis. This portion of the project provides for follow-on activities to include site investigations, feasibility studies, risk assessments, interim and site remedial actions as required for the multiple contaminated areas identified within the Center. The work follows the CERCLA process and incorporates the State of Ohio regulatory requirements, as specified under the issued Administrative Order by the State of Ohio Environmental Protection Agency (OEPA).

2. Remediation of Underground Storage Tank Sites, PBS 650,000

This project will provide for remediation of fuel contaminated sites around the facility. Prior investigations identified soil and groundwater contamination resulting from leaks and spills associated with previous operation of underground storage tank (UST) systems. The USTs were previously located in these areas, but have been removed. The soil and groundwater contamination will be remediated to conform with the federal RCRA, state and local UST requirements.

H. Marshall Space Flight Center (MSFC) $3,000,000

1. CERCLA Investigation and Cleanup 2,700,000

This project continues the effort to assess, characterize, and remediate site contamination identified at multiple areas within the Center, as caused by releases of hazardous contaminants into the environment. This phase of the project will provide follow-on actions to remedial investigations, site risk assessments, feasibility and treatability studies, and will provide for evaluation of remedial treatment alternatives and implementation of remedial actions for site cleanups. MSFC is listed on the Environmental Protection Agency's (EPA)National Priorities List (NPL).This work will follow the CERCLA process and a Federal Facilities Agreement between NASA, EPA and the State of Alabama.

2. RCRA Investigation and Cleanup, Santa Susana Field Laboratory (SSFL) *300,000*

This project continues the facility remediation program for the assessment, characterization, and cleanup of site contamination at identified RCRA Solid Waste Management Units (SWMUs). Contaminants, especially trichloroethylene, have migrated through the existing rock formation and overburden into the groundwater. This portion of the project will provide follow-on activities to groundwater contaminant characterization, risk assessments including interim removal action and corrective action evaluation and implementation for site cleanup. The project is required for compliance with RCRA and the State of California regulations.

I. Michoud Assembly Facility (MAF) $2,000,000

1. Remediation Activities, MAF 1,150,000

This project continues characterization and remediation activities associated with the Solid Waste Management Units (SWMUs) identified during the RCRA facility investigation. The scope of work includes removal actions, well installation, soil disposal, testing and evaluation of technologies for site cleanup, and corrective measures for the identified contaminated areas. The work will provide for activities identified in the Corrective Measures Study submitted to the regulatory agencies. The project follows requirements under the facility RCRA permit.

2. Install and Upgrade Secondary Containment Areas *850,000*

This project will provide for upgrades and modifications to approximately fifteen containment areas located around three sites in the facility. The modifications include modifying containment areas and installing chemical liners under tanks, repairing foundations, and ancillary improvements. These modifications will increase the center's ability to contain accidental spills of toxic chemicals. The project is required for compliance with the federal Clean Water Act (CWA),state and local environmental requirements.

J. Stennis Space Center (SSC) $3.700.000

1. Remediation of Building 2205 Sites 2,700,000

This work began as an emergency effort in FY 1995. The FY 1995 project was funded with residual Environmental Compliance and Restoration Program funds. This project continues the efforts to study and initiates cleanup of contamination at Sites 12A/16, 18 and 19/23. This portion of the work follows initial remedial activities that include remedial investigations, risk assessments, and feasibility studies. It will provide for treatability studies, interim removal actions as necessary, and remedial actions determined necessary to cleanup these sites. The project is required by federal and state requirements for compliance with RCRA and CERCLA.

2. Remediation of Site 6 Contamination 1,000,000

This work began as an emergency effort in FY 1995. The FY 1995 project was funded with residual Environmental Compliance and Restoration Program funds. This project continues the efforts to study and initiates cleanup of contamination around Building 6 site. This portion of the work follows initial remedial activities that include remedial investigations, risk assessments, and feasibility studies. It will provide for treatability studies, interim removal actions as necessary, and remedial actions determined necessary to cleanup the site. The project is required by federal and state requirements and will comply with RCRA and CERCLA.

K. Wallops Flight Facility (WFF) $300.000

1. Remediation of Contaminated Sites 300,000

The project continues the effort to characterize and reniediate soil and groundwater contamination at WFF. This portion of the project continues the implementation of remedial investigations and feasibility studies and initiates necessary remedial action approaches for cleanup of soil and groundwater contamination. The remedial actions will follow and conform with the federal, state and local requirements. The project is required for compliance with CERCLA.

L. White Sands Test Facility (WSTF) $2.800.000

1. Groundwater Contamination Assessment and Remediation 2,100,000

The project continues the effort to assess, characterize, and remediate soil and groundwater contamination at WSTF. This portion of the project continues the implementation of remedial action approaches for cleanup of groundwater contamination. The remedial actions will follow and conform with the federal, and the State of New Mexico regulatory requirements. The project is required to comply with the state issued RCRA 3008(h) consent order.

2. Replace Evaporation Tank Liners 700,000

The project will replace the hazardous waste storage tank liners located around the 200 Area. The project will satisfy the Center requirements under a State of New Mexico issued RCRA permit, requiring periodic replacement of the tank liners to ensure adequate containment of the stored hazardous wastes. The project consists of the removal and disposal of the tank contents, excavation, removal and replacement of the liners, backfilling, and proper disposal of removed materials. In addition, sampling and analyses will be performed at various locations to verify integrity of the system and identify any contamination.

M. Various Locations $285.000

1. Sewage Industrial Treatment Upgrade, Madrid, Spain 285,000

This project provides for the construction and installation of facilities to upgrade the Wastewater Treatment Plant (WTP) to provide effluent treatment for compliance with regulations. The upgrade will include the rerouting of facility drains to the WTP system, addition of chemical reagents dosing systems, chemical mixing and flocculation tanks, sand filter, pumping station, and the associated controls and metering devices. The upgrade will provide for compliance with Spanish Regulations and guidelines set forth by the European Economic Community. It will also allow the reuse of effluent water for imgation purposes.

N. Miscellaneous Projects Not in Excess of $250,000 Each $245.000

O. Studies Remedial Investigations, Feasibility Studies. Assessments Design. and Related Engineering $8.740.000

**Total Environmental Compliance and Restoration** **$34.000.000**

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED:

Approximately $45 - $55 million per year for the next few years is the current estimate for meeting environmental Compliance and Restoration requirements. This figure will become better defined as studies are completed and remediation projects are reviewed by Federal, state, and local regulators.

Inspector General

**INSPECTOR GENERAL**

**FISCAL YEAR 1998 ESTIMATES**

**BUDGET SUMMARY**

**OFFICE OF INSPECTOR GENERAL**

SUMMARY OF RESOURCES REQUIREMENTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Personnel & related costs | 14,865 | 15,750 | 16,900 |
| Travel | 585 | 700 | 800 |
| Operation of installation | 450 | 550 | 600 |
| Facilites services | (-) | (-) | (--) |
| Technical services | (250) | (350) | (300) |
| Management and Operations | (200) | (200) | (300) |
| Total. | 15,900 | 17,000 | 18,300 |
| Distribution of Program Amount by Installation | | | |
| Headquarters | 15,900 | 17,000 | 18,300 |
| Total. | 15,900 | 17,000 | 18,300 |

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**FISCAL YEAR 1998 ESTIMATES**

**OFFICE OF INSPECTOR GENERAL**

The NASA Office of Inspector General (OIG) budget request of $18.3 million for FY 1998 is based primarily on 198 Full-Time Equivalents (FTEs). Although the OIG has a 204 FTE ceiling, this staffing level is commensurate with the eventual goal of 198 FTE's projected for FY 2000. The FTE level includes plans to continue building an Information Technology Audit Group and a Computer Crimes Program. The personnel and related costs of the 198 FTEs represents approximately 92 percent of the total OIG budget request. This is barely the minimal staffing level that allows the OIG to perform its legislated mission. At the requested level the OIG will: provide assistance and work cooperatively with Agency management as it carries out NASA's programs and operations: 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: concentrate investigative resources on procurement fraud and computer crime matters including emphasis on prevention initiatives; work cooperatively with management by conducting inspections/assessments/reviews of issues identified by the OIG as well as those that are of concern to management: and 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. In light of increasing budget constraints, the Inspector General has commenced a streamlining activity which will increase the mission capability of the OIG staff. Initiatives include conversion of administrative overhead positions to program assistants responsible for assisting on direct mission activities of the audit, investigative, and inspection missions: staff reductions in the resources management division: and matrixing existing personnel and management analyst positions to support direct mission activities. In addition, the OIG will continue to streamline and simplify communication and report channels, and improve computer and telecommunications capacities to further increase staff capabilities.

As NASA continues to downsize, establish new priorities, and modify its programs and operations within proposed budget constraints, efforts will continue within the OIG to concentrate staff resources on those programs and operations identified as the most critical and vulnerable to fraud and abuse. Throughout this process, the OIG is increasing its cooperation with NASA management while assuring that the OIG's statutory independence is maintained. The OIG will continue to set priorities based on funding levels, program needs, Congressional and Administration concerns, and the results of OIG research and findings.

The OIG's mission is to conduct independent audits, investigations, and inspections/assessments/reviews of NASA's programs and operations while working cooperatively, as feasible, with NASA management and program managers. Audits will be prioritized and selected to evaluate programmatic, operational and financial management concerns, information technology systems and operations, and internal control vulnerabilities. The investigations program, with its computer crimes capability, will place greater emphasis on the investigation of computer intrusion and frauds in which the computer was used as an instrument of the crime. The investigations program remains focused on complex procurement and other fraud matters including fraud against the Government by contractor and Government employees and product substitution procurement

irregularities. Investigative matters will be approached on a programmatic, priority basis to identify preventive initiatives. 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 as identified by the OIG: and administrative inquiries related to unethical and improper conduct and waste and mismanagement.

## OBJECTIVES AND STATUS

This request represents the resources (FTEs) needed at NASA Headquarters and the field offices to fulfill the OIG mission. Recognizing that the identified audit, investigative, inspections, assessments, and other reviews workload significantly exceeds the available resources, continuous adjustments of priorities will be necessary to ensure that: balanced coverage of NASA's programs and operations is maintained: critical and sensitive matters are promptly evaluated and investigated; and all OIG customers receive timely, accurate, and complete responses.

The OIG audit, inspection and assessment, and partnerships and alliances programs set priorities for audits, evaluations, and reviews to maximize the return on available staff resources. These priorities are established and contained in strategic plans for each of NASA's strategic enterprises - Space Science, Aeronautical Research and Technolog, Mission to Planet Earth, Human Exploration and Development of Space, as well as supporting activities that include, financial management, management systems and facilities, and procurement. The OIG uses a formal, comprehensive process to identify, review, prioritize, and select the audits, evaluations, and reviews to be performed.

The OIG audit, inspection and assessment, and partnerships and alliances workloads and assignments are derived from: (1) monitoring NASA's evolving initiatives in downsizing, re-engineering, comercialization, 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 and compared to available resources and published in the annual OIG audit plan. The OIG will continue its NASA-wide program-oriented audit concept to obtain greater visibility and awareness of issues related to NASA's major programs and initiatives.

The defined audit workload far exceeds available staff. This will require continuous adjustment of priorities to provide balanced coverage of programs and operations most vulnerable to abuse and mismanagement. Further, program and project changes, growth, delays, and termination increase the need for OIG oversight of contractor/subcontractor/grantee cost, schedule, and performance effectiveness. NASA's continued reliance on contractors and grantees (about 90 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. NASA was billed approximately $18.4 million during FY 1996 for contract audit services.

The OIG plans to continue its NASA-wide program-oriented audit concept to ensure visibility and awareness of significant issues related to major NASA programs/projects. During FY 1998, the OIG will focus attention and provide support to program managers on issues relating to: Mission to Planet Earth, 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, and Facilities and Equipment. The OIG will focus on the security and integrity of NASA's major information systems and operations for the newly created Information Technology Audit Group.

The OIG will continue to monitor and assess NASA's high risk areas, material weaknesses and areas of significant concern to ensure that corrective actions are implemented timely. Areas of emphasis will include: financial systems-accounting: procurement and environmental programs; NASA information technology resources; institutional contracting practices: contract management: contractor-held property; contractor cost reporting: allotment and budgetary controls; and financial reporting/general ledger. Financial management's significance increased with the passage of the CFO Act. Pursuant to the Act, we have selected auditors 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.

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 inititatives; (2) management's actions 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 agency in information technology spending); (4) improvements in financial management systems, practices, controls, and information; (5) effectiveness of the audit follow-up system in enabling management to maintain the status of corrective actions: and (6) the adequacy of Agency-wide corrective actions addressing environmental concerns. These identified vulnerabilities are then evaluated, prioritized, and included in our plans for further action.

The OIG investigative workload continues to exceed the availability of investigative resources. The FY 1998 investigative staffing level will require OIG management to effectively manage the complex workload of investigative criminal and civil fraud matters. The establishment of the Computer Crimes Division will allow the OIG to investigate unauthorized intrusions into and compromises of NASA and contractor computer systems, as well as, assess the Agency's vulnerability to information terrorism. The number of complex procurement fraud cases also remains high. Such cases take longer to resolve and are resource intensive, thereby limiting our flexibility to improve and expand the program. To provide us a greater capability to be more proactive, we have established a Proactive Programs Division and a Program Fraud Division to focus on program fraud areas which have been identified by our audits as highly vulnerable to fraud. The quantity of investigative allegations received further adversely affects the timely completion of ongoing cases. To help us address all substantive allegations received, we are working with management 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 matters to the OIG Inspections and Assessments (I&A) staff for review, Investigative managers are assessing the allegations and cases on a programmatic basis to determine their seriousness

and impact to the programs in meeting their objectives. By referring matters to Agency managers and the I&A staff to resolve, we can reserve our investigative resources to address the more serious allegations made to the OIG.

In summary, the OIG will collaborate with Agency management to address issues of joint concern and to improve the scope, timeliness. and thoroughness of its oversight of NASA programs and operations, identify preventive measures, and enhance its capability to assist NASA management to efficiently and effectively achieve program and project goals and objectives.

## MEASURES OF PERFORMANCE

| WORKLOAD | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| Office Staff Goals | | | |
| Full-Time Equivalents | 190 | 198 | 198 |
| Investigations | | | |
| Cases pending beginning of year | 356 | 328 | 318 |
| Opened during year | 206 | 210 | 200 |
| Closed during year | 234 | 220 | 210 |
| Cases pending end of year | 328 | 318 | 308 |
| Audits | | | |
| Audits pending beginning of year | 59 | 71 | 65 |
| Opened during year | 46* | 52* | 60* |
| Closed during year | 34 | 58 | 58 |
| Audits pending end of year | 71 | 65 | 67 |
| Inspections & Assessments (IA) and Partnerships & Alliances (PA) | | | |
| IA Administrative Investigations pending beginning of year | 0 | 13 | 20 |
| Opened during year | 25 | 50 | 60 |
| Closed during year | 12 | 43 | 60 |
| IA Administrative Investigations pending end of year | 13 | 20 | 20 |
| IA and PA Reviews pending beginning of year | 0 | 10 | 11 |
| Opened during year | 23 | 33 | 33 |
| Closed during year | 13 | 32 | 33 |
| IA and PA Reviews pending end of year | 10 | 11 | 11 |

*Emphasis on programmatic audits

## BASIS OF FY 1998 FUNDING REQUIREMENT

### PERSONNEL AND RELATED COSTS

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | (Thousands of Dollars) | | |
| Compensation and Bene | 14,680 | 15,320 | 16,900 |
| Compensation | 12,230 | 12,720 | 13,791 |
| (Full-time permanent) | (11,770) | (12,260) | (13,400) |
| (Other than full-time permanent) | (200) | (200) | (185) |
| (Overtime & other compensation) | (260) | (260) | (206) |
| Benefits | 2,450 | 2,600 | 2,609 |
| Supporting Costs | 185 | 430 | 500 |
| Transfer of personnel | 100 | 250 | 300 |
| Personnel training | 75 | 170 | 190 |
| OPM Services | 10 | 10 | 10 |
| Total | 14,865 | 15,750 | 16,900 |

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | (Full-Time Equivalents) | | |
| Full-time permanent | 180 | 196 | 196 |
| Other controlled FTEs | 10 | 2 | 2 |
| Total | 190 | 198 | 198 |

These estimates provide for establishment of NASA OIG's Information Technology Audit and Computer Crimes Divisions.

## TRAVEL

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Travel | 585 | 700 | 800 |

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 newly created 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

| | FY 1996 | FY 1997 | FY 1998 |
|---|---|---|---|
| | | (Thousands of Dollars) | |
| Technical Services | 250 | 350 | 300 |
| Management and operations | 200 | 200 | 300 |
| To | 450 | 550 | 600 |

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 1998 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, [$17,000,000] *$18,300,000.* (*Departments of Veterans Affairs* and Housing and Urban *Development,* and *Independent* Agencies Appropriations *Act. 1997.)*

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