SCIENCE, AERONAUTICS AND TECHNOLOGY
FY 1998 ESTIMATES
BUDGET SUMMARY

OFFICE OF SPACE SCIENCE

SUMMARY OF RESOURCE REQUIREMENTS

Space Science	FY 1996	FY 1997	FY 1998
* Advanced x-ray astrophysics facility (AXAF)	237,600	178,600	92,200
* Space Infrared Telescope Facility	--	--	81,400
* Relativity mission	51,500	59,600	45,600
* Cassini	191,500	89,600	9,000
* Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)	--	18,200	48,200
Payload and instrument development	25,900	16,900	12,300
* Explorers	132,200	125,000	142,700
* Discovery	102,200	76,800	106,500
* Mars surveyor	111,900	90,000	139,700
* New Millennium	43,500	48,600	75,700
Advanced space technology	143,300	132,000	151,200
Mission operations and data analysis	563,600	583,300	507,400
Supporting research and technology	239,400	246,000	311,200
Suborbital program	88,000	64,100	84,400
Launch services	245,300	240,600	236,300
Total	**2,175,900**	**1,969,300**	**2,043,800**

* Total Cost information is provided in the Special Issues section

Distribution of Program Amount by Installation	FY 1996	FY 1997	FY 1998
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**

SCIENCE, AERONAUTICS AND TECHNOLOGY
FISCAL YEAR 1998 ESTIMATES

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 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

Morover, new space science discoveries offer other tangible returns: for example, it may soon be possible to characterize "space weather" 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-long chain 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;
- 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;
- 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.
- 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.

ADVANCED X-RAY ASTROPHYSICS FACILITY

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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-ray background 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

Performance Milestone	Plan	Actual/Revised	Description/Status

AXAF Observatory CDR	February 1996	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	April 1996	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	August 1996	January 1997 (HRC) & 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	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	April 1997	--	Verification of end-to-end optical performance. On schedule

Begin Observatory assembly and test	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	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	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 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.

SPACE INFRARED TELESCOPE FACILITY

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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 modern instrumentation to be brought to bear, across the entire electromagnetic spectrum, on the central questions of modern 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 modern 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 (which judged 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, $117.3 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

Performance Milestone	Plan	Actual/Revised	Description/Status
Non Advocate Review (NAR)	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	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	April 1998	--	Approval by NASA to proceed with the design and development of the SIRTF project
Critical Design Review	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	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.

RELATIVITY MISSION

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
Relativity mission development	51,500	59,600	45,600

* Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. This is the most accepted theory of gravitation and of the large-scale structure of the Universe. General relativity is a cornerstone of our understanding of the physical world, and consequently of our interpretation of observed phenomena. However, it has only been tested 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

Performance Milestone	Plan	Actual/Revised	Description/Status
Flight Model Dewar Delivery	November 1996	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	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	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	April 1998	--	Successful interface of the dewar to the science payload. Expected to be completed early.
Launch	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.

CASSINI DEVELOPMENT

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

Performance Milestone	Plan	Actual/Revised	Description/Status
Start System Level Tests	May 1996	May 1996	Integration, test and checkout of flight hardware and instruments
Deliver Flight Model Science Instruments	July 1996	July 1996	Delivery of flight model instruments to JPL for integration with the spacecraft.
Start Spacecraft Environmental Tests	October 1996	October 1996	Tests entire spacecraft performance in a simulated mission environment to assure proper operation in space
Ship spacecraft to KSC	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	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 flight 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.

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

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

PAYLOAD AND INSTRUMENT DEVELOPMENT

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
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 GOALS

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 '96 mission, 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:

Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
TSS launch	February 1996	February 1996	Operations conducted aboard Shuttle mission STS 75.

Astro-E:

Performance Milestone	Plan	Actual/Revised	Description/Status
Engineering model spectrometer delivery	April 1996	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	October 1996	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	July 1997	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:

Performance Milestone	Plan	Actual/Revised	Description/Status
Deliver MOx Sensor Head	May 1996	May 1996	Provide two refurbished MOx sensor heads to Russia for spacecraft integration
Spacecraft launch	November 1996	November 1996	Launched on Russian Proton booster; failed

Performance Milestone	Plan	Actual/Revised	Description/Status
SAC-B/HETE launch	November 1995	November 1996	Delayed pending Pegasus launch vehicle recovery. Launch failure in November 1996.
Cluster launch	November 1995	June 1996	Delayed by ESA until May 1996 due to Ariane-V launch vehicle problems. Launch failure in June 1996.
VSOP launch	September 1996		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.

EXPLORER PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

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, Cornell 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)

Performance Milestone	Plan	Actual/Revised	Description/Status
Instrument deliveries complete	December 1996	October 1996	All instruments ready for physical integration with the spacecraft
Begin environmental tests	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	July 1997	--	Spacecraft system level testing successfully complete. Move to KSC for integration with Delta II launch vehicle. Ahead of schedule.
Launch	December 1997	--	Possible earlier launch

Far Ultraviolet Spectroscopy Explorer (FUSE)

Performance Milestone	Plan	Actual/Revised	Description/Status
Mission CDR	April 1996	April 1996	Confirmed that the mission design is sound.
Spacecraft CDR	June 1996	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	June 1997	--	Begin to assemble and test major components. On schedule
Launch	October 1998	--	On schedule.

Medium-class Explorer Progam

Performance Milestone	Plan	Actual/Revised	Description/Status
Step 2 Selections	March 1996	April 1996	Two missions selected for start of Phase B definition studies.
IMAGE PDR	January 1997	--	Approve for more detailed design analysis, and confirm that science objectives are achievable. On schedule
IMAGE Spacecraft CDR	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	February 1998	--	Integrate and test major instrument components. On schedule.
IMAGE - Begin S/C System I&T	August 1998	--	Integrate and test major spacecraft subsystems. On schedule for launch by the first quarter of FY 2000.
MAP Mission PDR	January 1997	--	Confirmation leading to Phase C/D. On schedule.
MAP Mission CDR	July 1997	--	Confirmation that the mission design is sound. On schedule.
MAP - Begin Instrument I&T	October 1997	--	Integrate and test major instrument components. On schedule for launch by the first quarter of FY 2001.

Performance Milestone	Plan	Actual/Revised	Description/Status
Transition Region and Coronal Explorer (TRACE) Start integration and test	August 1996	August 1996	Begin to assemble major components onto the spacecraft
Ship TRACE to launch site	September 1997	--	Move to KSC for integration with the launch vehicle. On schedule.
TRACE Launch	October 1997	--	On schedule, but depends on Pegasus return to flight.
Wide-field Infrared Explorer (WIRE) Start integration and test	October 1997	--	Begin to assemble major components onto the spacecraft. On schedule.
WIRE Launch	August 1998	--	On schedule, but depends on Pegasus return to flight

University-class Explorer Progam

Performance Milestone	Plan	Actual/Revised	Description/Status
Release of AO	2nd Qtr FY 1997	--	Release an Announcement of Opportunity (AO) for the first round of UNEX missions.
Complete selection	4th Qtr FY 1997	--	Select the first round of UNEX missions and initiate development activities
First UNEX mission launch	4th Qtr FY 1999	--	Launch the first UNEX mission aboard an Ultra-Lite Class ELV.

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.

DISCOVERY PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
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-II 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

Performance Milestone	Plan	Actual/Revised	Description/Status
Flight qualification complete	December 1995	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)	August 1996	August 1996	Spacecraft shipped to Kennedy Space Center (KSC) in August 1996 for integration with Delta II launch vehicle.
Launch	December 1996	December 1996	Development phase complete; successful launch.

Lunar Prospector

Performance Milestone	Plan	Actual/Revised	Description/Status
Instrument Delivery for I&T	October 1996	November 1996	Flight model spacecraft subsystems and instruments completed. Begin system level integration and test phase.
Test Readiness Review	November 1996	November 1996	Flight System test Readiness Review ensures that the flight systems are prepared for environmental testing.
Launch	October 1997	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

Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
System Requirements Review	April 1996	April 1996	Ensures mission requirements can be met with current technology and expected developments.
Technical Design Review	October 1996	September 1996	Review assured readiness to proceed with detailed design and development.
Preliminary Design Review (PDR)	October 1996	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	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	January 1998	--	Begin to integrate major components of the spacecraft onto the spacecraft structure. On schedule.
Start environmental tests	June 1998	--	Begin tests to demonstrate that the assembled spacecraft can withstand the launch and space environments. On schedule.

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.

MARS SURVEYOR PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
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 PERFORMANCE

Mars Global Surveyor

Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
Instrument Calibration and Test	December 1995	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	February 1996	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	August 1996	August 1996	Assure that flight hardware integration is complete and ready for final acceptance tests.
Operational Readiness Review	October 1996	August 1996	Formal review approving test results and recommending mission launch. Schedule accelerated to August 1996.
Launch	November 1996	November 1996	Launched November 7, 1996. Spacecraft in cruise mode to Mars.

1998 Mars Surveyor Orbiter and Lander

Performance Milestone	Plan	Actual/Revised	Description/Status
Preliminary Design Review (PDR)	March 1996	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	April 1996	April 1996	Confirmed that tentatively selected payload can be accommodated within the spacecraft specifications.
Spacecraft Systems Critical --Design Review (CDR)	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	May 1997	--	Integrate instruments and spacecraft subsystems. On schedule.
Start Lander Integration and Test	July 1997	--	Integrate instruments and spacecraft subsystems. On schedule
Start Lander environmental tests	November 1997	--	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. On schedule.
Start Orbiter environmental tests	November 1997	--	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. On schedule.
Ship Orbiter spacecraft	August 1998	--	Ship to the launch site. On schedule for December 1998 launch.

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

Performance Milestone	Plan	Actual/Revised	Description/Status
Critical Design Review	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	2nd Qtr FY 2001	--	Ship to KSC launch site
Launch	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, 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.

NEW MILLENNIUM PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
New Millennium Spacecraft	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

Performance Milestone	Plan	Actual/Revised	Description/Status
Deep Space (DS) Mission II Design Review	February 1996	February 1996	Initial Deep Space (DS) II system level design and technologies identified.
DS Mission I Project Review	April 1996	May 1996	Peer review of complete system and subsystem designs, ready for Detailed Design Concurrence and fabrication.
DS Mission I Implementation	May 1996	May 1996	Award contract for fabrication, assembly, test and operations of DS I.

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

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

Performance Milestone	Plan	Actual/Revised	Description/Status
Testbed demonstration	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	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 (RPS Phase 1)	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	3rd Qtr 1999	--	CISM development of three-dimensional multi-chip modules to perform most spacecraft electronic functions.
"Flight-like" model demo: X2000	4th Qtr 1999	--	X2000 integrated advanced spacecraft system (spacecraft hardware, software, mission operations) demonstrated in testbed
"18 month launch ready"	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	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)	Plan: 2003	--	Modular, high-efficiency power source incorporating new heat source design for drastically reduced mass and radioisotope content.
"Flight-like" model demo: X2003	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"	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.

ADVANCED SPACE TECHNOLOGY

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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-term 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-term (< 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 PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status

Complete the development of a high-efficiency (50%) Traveling Wave tube (TWT) for Ku-Band (12-14 gigahertz (Ghz)) for satellite applications	February 1996	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	2nd Qtr FY 96	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	July 1996	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	4th Qtr FY 1996	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.
Initial demonstration of a 800- gigahertz local oscillator with planar diodes for sub-millimeter astrophysics applications	4th Qtr FY 1996	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	4th Qtr FY 1996	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	4th Qtr FY 1996	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	4th Qtr FY 1996	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"	4th Qtr FY 1996	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	4th Qtr FY 1996	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.

Conduct demonstrations of autonomous 100-acre robotic crop harvesting	4th Qtr FY 1996	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	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	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	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.	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	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	4th Qtr FY 1996	TDB	This breadboard refrigerator/freezerwould store biological specimens on the Space Station. Funding constraints forced delay of this effort. Completion would be managed and funded by the Space Station.
Demonstrate advanced Ni-Hydrogen battery	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	September 1996	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.	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	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)	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	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	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.
Conduct on-orbit Ranger telerobotic flight experiment	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	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	4th Qtr FY 1997	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	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 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 (2.5 Thz) 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.

MISSION OPERATIONS AND DATA ANALYSIS

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

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 (1995), 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 UV and x-ray emissions affecting the Earth's upper atmosphere, the geospace environment, and the heliosphere. Geotail is a Japan-U.S. spacecraft that explored the deep geomagnetic tail in its first two years of flight and now is exploring the near-tail region on the night side and the magnetopause on the 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 arrive 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

Performance Milestone	Plan	Actual/Revised	Description/Status

Cargo Integration Review for the Second Servicing Mission	March 1996	March 1996	Completed the coordination of HST flight hardware and carriers with JSC shuttle payload integration.
Advanced Camera System Critical Design Review	April 1996	April 1996	Validate design maturity in preparation for system fabrication
Deliver NICMOS/STIS to GSFC	August 1996	August 1996	Instrument development activities completed; instruments shipped to GSFC to begin final integration and testing
2nd Servicing Mission	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	February 1996	February 1996	First major delivery of on-line system hardware and software for integrated systems testing
Advanced Camera System Alignment Completed	September 1997	--	Complete optical alignment in preparation for final integration and test, prior to shipment to GSFC. On schedule.
Advanced Camera delivered to GSFC	July 1998	--	Allows for final testing prior to shipment to the launch site. On schedule.
AXAF			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
AXAF Science Center End-to End CDR	January 1997	--	Validate design maturity in preparation for ASC system development. On schedule
Ground systems ready to support Integration and Test	July 1997	--	Able to proceed with spacecraft integration and test activities. On schedule.

Ground System Release #4	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			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
Return Probe Data	May 1996	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	July 1996	July 1996	Transmit to Earth, science data and imagery from encounters with Jupiter and its moon Io.
Ganymede Encounter	July 1996	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	November 1996	November 1996	Encounter and data playback were successfully executed.
Europa Encounter	December 1996	December 1996	Execute closest ever flyby of Europa and transmit playback data.
Various Encounters	1997 and 1998	--	Execute 2 Europa, 2 Ganymede and 2 Callisto encounters and transmit playback data approximately 2 months after encounter.
NEAR			
Mathilde Encounter	June 1997	--	Flyby the asteroid Mathilde, largest asteroid (60 km diameter) observed by spacecraft. On schedule.
Mars Global Surveyor			
Mars orbit insertion	September 1997	--	Burn to insert into Mars capture orbit. On schedule.

Initiate Mapping Operations	March 1998	--	Initiate 2 years of science data acquisition on Mars composition, topography, atmosphere, and magnetic fields. On schedule.
Mars Pathfinder			
Mars Landing	July 1997	--	Lander lands on Martian surface, transmits engineering and science data back to Earth. On schedule
Cassini			
Deep Space Maneuver	March 1998	--	Burn to target first Venus-Flyby gravity assist. On schedule.
Venus Flyby	April 1998	--	First Venus flyby gravity assist. On schedule
Planetary Flight Support			
Begin Cassini Pre-Launch Operations	August 1996	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	August 1996	August 1996	Hardware and telemetry and command software to support launch of the Mars Global Surveyor spacecraft
Mars Pathfinder Ground System	August 1996	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	October 1996	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	(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.

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 UV 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 "windsock 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.

SUPPORTING RESEARCH AND TECHNOLOGY

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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.

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

Performance Milestone	Plan	Actual/Revised	Description/Status
Complete SIRTF Phase A studies	September 1996	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)	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	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	September 1996	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.
Develop self-replicating systems to model Earth's earliest life	September 1996	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	September 1996	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	September 1996	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	(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	(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).
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)	--	Important 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.
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.
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.

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.

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 **Plan**	FY 1996 **Actual**	FY 1997 **Plan**	FY 1997 **Revised**	FY 1998 **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 roadmaps 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.

SUBORBITAL PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

Performance Milestone	Plan	Actual/Revised	Description/Status
RFP Released	February 1996	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	April 1996	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	August 1996	December 1996	Selection of the SOFIA development and operations prime contractor.

System Requirements Review	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	August 1997	--	Formal review of the German contractor's concept for implementation of the telescope assembly. On schedule.
System Preliminary Design Review	April 1998	--	Review of the U.S. contractor's concept for development and integration of the observatory. On schedule
Balloon Program			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
--	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 flights are planned
Sounding Rockets			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
--	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			

Performance Milestone	Plan	Actual/Revised	Description/Status
--	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.

LAUNCH SERVICES

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	**FY 1996**	**FY 1997**	**FY 1998**
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

Performance Milestone	Plan	Actual/Revised	Description/Status
SNOE launch	May 1997	--	Launch aboard a Pegasus launch vehicle. On schedule.
TERRIER launch	August 1997	--	Launch aboard a Pegasus launch vehicle. On schedule
CATSAT launch	3rd Qtr FY 1998	--	Launch aboard a Pegasus launch vehicle. On schedule
Small Class Launch Vehicles			
FAST launch vehicle.	TBD	August 1996	Launch successfully from VAFB board the Pegasus XL/L1011 on August 21, 1996.
SAC-B/HETE launch	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	TBD	--	Exact date of this launch is dependent upon successful return to flight of the redesigned Pegasus XL launch vehicle.
TRACE launch	October 1997	--	Exact date of this launch is dependent upon successful return to flight of the redesigned Pegasus XL launch vehicle.
WIRE launch	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			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
Deep Space I launch	July 1998	--	On schedule for launch aboard a Delta 7326 launch vehicle.
FUSE launch	October 1998	--	On schedule for launch aboard a Delta 7320 launch vehicle.
Medium Class Launch Vehicles			
Performance Milestone	**Plan**	**Actual/Revised**	**Description/Status**
NEAR launch	February 1996	February 1996	Launched successfully February 17, 1996, aboard a Delta II launch vehicle.
Polar launch	February 1996	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	November 1996	November 1996	Launched successfully aboard a Delta II launch vehicle on November 7, 1996.
Mars Pathfinder launch	December 1996	December 1996	Launched successfully aboard a Delta II launch vehicle on December 4, 1996.
ACE launch	September 1997	--	On schedule for launch aboard a Delta-II, D7925
All Other Classes of Launch Vehicles:			

Performance Milestone	Plan	Actual/Revised	Description/Status
Cassini launch	October 1997	--	Launch aboard a Titan IV/Centaur launch vehicle. On schedule.
AXAF-I launch	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.