SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE | **SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
* Advanced x-ray astrophysics facility	112,200	41,000	--	SAT 1-09
* Space infrared telescope facility......................................	70,200	119,700	125,000	SAT 1-12
* Hubble space telescope (development)	144,900	161,400	140,400	SAT 1-15
* Relativity (GP-B) mission	70,800	57,400	40,500	SAT 1-17
* Thermosphere, ionosphere, mesosphere energetics and dynamics	64,400	49,300	16,000	SAT 1-20
* Stratospheric observatory for infrared astronomy	45,800	58,200	45,100	SAT 1-22
Payload and instrument development...............................	18,000	28,900	10,000	SAT 1-25
* Explorers...	169,300	196,000	151,000	SAT 1-29
* Discovery	100,000	124,900	180,500	SAT 1-37
* Mars surveyor	187,900	228,400	250,700	SAT 1-41
Mission operations	138,700	106,300	85,300	SAT 1-46
Supporting research and technology.................................	894,000	945,200	1,152,100	SAT 1-54
Launch services..	27,600	--	--	SAT 1-80
Construction of facilities (building 21 @ GSFC)	--	2,500	--	
Expendable launch vehicles (non-add and included above)	[212,900]	[206,500]	[186,900]	
Total...	2,043,800	2,119,200	2,196,600	

*Total Cost information is provided in the Special Issues section

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2000 ESTIMATES

BUDGET SUMMARY

Distribution of Program Amount by Installation	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Johnson Space Center	11,069	14,395	10,538
Kennedy Space Center	127,988	206,166	184,142
Marshall Space Flight Center	238,014	174,057	142,012
Ames Research Center	81,944	108,822	99,381
Langley Research Center	16,474	11,991	10,884
Glenn Research Center	32,121	22,141	20,720
Goddard Space Flight Center	793,997	790,781	786,253
Jet Propulsion Laboratory	668,180	720,947	892,917
Headquarters	74,013	69,900	49,753
Total	2,043,800	2,119,200	2,196,600

PROGRAM GOALS

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

The mission of the Space Science Enterprise is to solve mysteries of the universe, explore the solar system, discover planets around other stars, search for life beyond Earth; from origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets, and life.

In pursuing this mission, we develop, use, and transfer innovative space technologies that provide scientific and other returns to all of NASA's Enterprises, as well as globally competitive economic returns to the Nation. We also use our knowledge and discoveries to enhance science, mathematics, and technology education and the scientific and technological literacy of all Americans.

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

How did the universe, galaxies, stars, and planets form and evolve? How can our exploration of the universe and our solar system revolutionize our understanding of physics, chemistry, and biology?

Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

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

Establish a virtual presence throughout the solar system, and probe deeper into the mysteries of the universe and life on Earth and beyond—a goal focused on the fundamental science we will pursue;

Pursue space science programs that enable, and are enabled by, future human exploration beyond low-Earth orbit—a goal exploiting the synergy with the human exploration of space;

Develop and utilize revolutionary technologies for missions impossible in prior decades—a goal recognizing the enabling character of technology; and

Contribute measurably to achieving the science, mathematics, and technology education goals of our nation, and share widely the excitement and inspiration of our missions and discoveries—a goal reflecting our commitment to education and public outreach.

STRATEGY FOR ACHIEVING GOALS

Science

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

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

Fulfilling one major commitment of previous strategic planning, the Enterprise will complete the deployment of the four "Great Observatories" with the launch of the Advanced X-ray Astrophysics Facility (AXAF) in 1999 and the Space Infrared Telescope Facility (SIRTF) in 2001. Complementing the discoveries of the Hubble Space Telescope and the Compton Gamma Ray

Observatory launched earlier in this decade, AXAF and SIRTF are certain to add to this bounty and help unravel the mysteries of the universe.

With the July 4, 1997, landing of the Mars Pathfinder, and the 1998 discovery of water ice on the Moon by Lunar Prospector (both missions of the Discovery series of spacecraft), the Enterprise visibly demonstrated that such "faster, better, cheaper" programs can yield exciting and inspiring achievements as well as a wealth of knowledge. Through programs such as Discovery and Explorer, the Enterprise will continue to accept prudent risk, shorten development time, explore new conceptual approaches, streamline management, and make other changes to enhance efficiency and effectiveness.

A key aspect of our strategic planning is to ensure the Enterprise acquires the advice of the external science community, and in particular the National Academy of Sciences. The Enterprise is also ensuring science community input by utilizing peer review in the Discovery, Explorers and Supporting Research and Technology programs. In addition, there is extensive collaboration with this community, international partners, and other federal agencies, such as the National Science Foundation, Department of Defense, and Department of Energy, in the conduct of our missions, research and technology.

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

Education and public outreach

Our education and public outreach goals and objectives involve establishing new directions for the Space Science Enterprise. The traditional role of the Enterprise in supporting graduate and postgraduate professional education—a central element of meeting our responsibility to help create the scientific workforce of the future—is being expanded to include a special emphasis on pre-college education and on increasing the public's knowledge, understanding, and appreciation of science and technology.

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

To achieve our education and public outreach goals and objectives, the Space Science Enterprise will adopt the following operating principles. The Space Science Enterprise will:

- Involve scientists in education and outreach in ways that enhance core Space Science research goals

- Make a long-term sustained commitment to integrating education and outreach into Space Science missions and research programs by: 1) providing resources; 2) building education and outreach into all aspects of the Space Science program; and 3) recognizing and rewarding contributions to education and outreach

- Support local, state, and national efforts directed towards systemic reform of science, mathematics, and technology education in close coordination with NASA's Education Division

- Base Space Science-developed educational products and activities on the criteria contained in the national Mathematics, Science, and Technology Education Standards

- Provide meaningful opportunities for student and teacher participation in Space Science research programs and missions and, in particular, emphasize the development of new opportunities for participation by underserved and underutilized groups

- Enhance the breadth and effectiveness of partnerships among scientists, educators, contractors, and professional organizations as the basis for Space Science education and outreach activities by: 1) focusing on high-leverage opportunities; 2) building on existing programs, institutions, and infrastructure; 3) emphasizing collaborations with planetariums and science museums; 4) coordinating with other ongoing education and outreach efforts inside NASA and within other government agencies; and 5) involving the contractors in the Space Science Enterprise's education/outreach programs

- Make materials widely available and easily accessible, using modern information and communication technologies where appropriate

- Evaluate its education and outreach programs for quality, impact, and effectiveness

The comprehensive approach to education and public outreach developed by the Space Science Enterprise to put these principles into practice is described in more detail in the October 15, 1996 report "Implementing the Office of Space Science Education/Public Outreach Strategy", available in full on the World Wide Web at http://www.hq.nasa.gov/office/oss/edu/imp_plan.htm

The approach outlined in this report has been explicitly designed to take advantage of, be coupled to, be compatible with, and build upon the very large investments in education being made by school districts, individual states, and other federal agencies—particularly by the National Science Foundation and the Department of Education. By pursuing such a systematic approach, the impact of a modest investment in education and outreach can be enormously amplified, thereby enabling the Space Science

Enterprise to make a significant, long-term, and long-lasting contribution to education and the public understanding of science in the United States.

During FY 2000, we will successfully achieve at least 7 of the following 8 objectives. 1) Each new Space Science mission will have a funded education and outreach program. 2) By the end of FY00 10% of all Space Science research grants will have an associated education and outreach program underway. 3) 26 states will have Enterprise-funded education or outreach programs planned or underway. 4) At least 5 research, mission development/operations or education programs will have been planned/undertaken in HBCUs, HSIs, or Tribal Colleges, with at least one project underway in each group. 5) At least 3 national and two regional educational or outreach conferences will be supported with a significant Space Science presence. 6) At least 3 exhibits or planetarium shows will be on display. 7) An on-line directory providing enhanced access to major Space Science-related products and programs will be operational by end of the fiscal year. 8) A comprehensive approach to assessing the effectiveness and impact of the Space Science education and outreach efforts will be under development, with a pilot test of the evaluation initiated.

Technology development and transfer

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

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

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

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

We have identified a number of key capabilities for which we are developing near-term (several years), measurable performance objectives. Achieving these objectives will require significant near-term investment. The objectives are part of an integrated technology roadmap which contains milestones against which our progress will be assessed.

To develop these capabilities, the Space Science Enterprise technology program is organized into three elements:

1. A *Core Program* of research supporting mission-specific technologies for Space Science and cross-cutting spacecraft and robotics technologies for multiple NASA Enterprises. The Core Program supports enabling technologies for the next generation of high performance and cost-effective Space Science missions. Retiring technological risk early in the mission design cycle, while emphasizing innovation to reach previously unattainable goals in mass reduction and performance, are key to the success of many of the missions planned for the next century.

   Cross-Enterprise technology development is generally multi-mission in nature and tends to focus on the earlier stages of the technology life-cycle. Emphasis is on basic research into physical principles, formulation of applications concepts, and component-level performance evaluation. While these developments may extend all the way to subsystem-level development and test for nearer-term missions, the focus of this program is on technological developments to enable revolutionary rather than incremental increases in capability and/or efficiency. These cross-cutting developments are the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions. Starting in FY 2000, new funding in Cross-Enterprise technologies is provided for technology initiatives to increase NASA's space science return many fold through revolutionary capabilities in the areas of networking, intelligent systems, nanotechnology, communications, lightweight structures, miniaturization, mobility, and propulsion for future robotic spacecraft and rovers.

2. Several *Focused Programs* are dedicated to specific high-priority technology areas. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. This approach can encompass developments from basic research all the way to infusion into science missions. The requirements are driven by the needs of Space Science, but other Enterprises are likely to benefit from them. Focused programs also includes mission studies, which is the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions by fully exploring the design and cost trade space. These studies will utilize new techniques for integrated design and rapid prototyping to ensure that realistic and implementable decisions are reached.

   There are four Focused Programs:

   <u>Advanced Deep Space System Development</u>. This program will develop, integrate, and test revolutionary technologies for solar system exploration. Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. Along with other technologies, these will be integrated as advanced engineering-model flight systems to form the basis for the new generation of survivable, highly capable micro-spacecraft.

Astronomical Search for Origins Technology. This program will develop critical technologies for studies of the early Universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, optical delay lines, and other technologies for space-based interferometry. Also included are technologies such as inflatable structures and large lightweight optics required by many proposed missions and concepts.

Structure and Evolution of the Universe Technology. This program will provide the technologies required for missions focused on understanding how the structure of our Universe emerged from the Big Bang, how the Universe is continuing to evolve, and what will be the fate of the Universe. Examples of technology in this area include sensors, detectors, and other instruments, as well as cryocoolers and lightweight optical systems.

Sun-Earth Connections Technology. This program will develop the technologies needed for missions focused on understanding long-term and short-term solar variability, and how solar processes affect the Earth. Technologies supported in this area include thermal shielding, integrated fields and particles sensors, high-temperature solar arrays, nanosatellites, and satellite constellations.

3. A *Flight Validation Program* called the "New Millennium Program" completes the technology development process by providing flight validation of breakthrough technologies to enable new science missions. New Millennium is driven by the need to reduce the cost of future science missions, mitigate the risk to the first users of new technologies, and to rapidly infuse new technologies into future missions. In keeping with the focus of the New Millennium Program (NMP) on providing flight validation of broadly applicable technologies, the NMP Deep Space-3 flight demonstrator project has been moved to the Astronomical Search for Origins focused program. This demonstrator will validate interferometry technologies to benefit future Origins missions such as Terrestrial Planet Finder. Similarly, the Deep Space-4 mission (Champollion) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme. The New Millennium Program is jointly funded by the Space Science Enterprise and the Earth Science Enterprise.

SCHEDULE & OUTPUTS

The Office of Space Science (OSS) has continued to work with the Office of Management and Budget and the NASA Advisory Committee to develop metrics in response to the Government Performance and Results Act (GPRA) of 1993. We have developed metrics for each individual Space Science program that will be incorporated into the Enterprise’s FY 2000 Performance Plan. These metrics are reflected in the “Measures of Performance” section for each program below.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED X-RAY ASTROPHYSICS FACILITY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Advanced X-Ray Astrophysics Facility development *........	112,200	41,000	--
ELV (Non-add	[8,300]	[2,000]	[--]

* 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. AXAF will be able to resolve and detect individual bright binary sources in galaxies within the Virgo cluster, as well as 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 its composition 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 was 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 decreasing future funding projections for NASA programs. The original baseline was an observatory with six mirror pairs, a 15-year mission in low-Earth orbit, and shuttle servicing. The restructuring produced AXAF-I, an observatory with four mirror pairs to be launched into a high-Earth orbit for a five-year lifetime, and AXAF-S, a smaller observatory flying an X-Ray Spectrometer (XRS). A panel from the National Academy of Sciences (NAS) endorsed the restructured AXAF program. The FY 1994 AXAF budget was reduced by Congress, resulting in termination of the AXAF-S mission. The Committees further directed that residual FY 1994 AXAF-S funds be applied towards development of a similar instrument payload on the Japanese Astro-E mission to mitigate the science impact of losing AXAF-S. Funding for Astro-E is requested within the Payload and Instrument Development line.

SCHEDULE & OUTPUTS

Deliver Observatory to KSC Plan: June 1998 Revised: January 1999	Observatory integration and systems testing completed at TRW. Ship to launch site and begin integration with upper stage, final performance testing, and integration in Shuttle. Delayed by need for additional testing and review to ensure mission success.
Launch Observatory Plan: August 1998	Shuttle deployment into low-Earth orbit followed by upper stage delivery to highly elliptical operational orbit. Delayed until April 1999 by need for additional testing and review to ensure

Revised: April 1999/Under Review	mission success. Additional delay, yet to be determined, will result from recently discovered problems with circuit boards.

ACCOMPLISHMENTS AND PLANS

As a result of delays at TRW, first identified over a year ago, the delivery of AXAF has slipped to January 1999, and the launch is now scheduled for April 1999. This delay was caused by the need to perform additional software development and testing, as well as the need for TRW to provide sufficient assurance to NASA that the spacecraft systems and both ground and flight software and procedures have been tested sufficiently to enable a successful mission. Unlike the Hubble Space Telescope, AXAF will not be serviceable on orbit by the Space Shuttle after deployment. Accordingly, NASA believes that it was prudent to conduct additional reviews prior to launch.

The delays have, to date, added about eight months to the schedule that was established over six years ago, and have added approximately $49 million (about 3%) to the cost of building and launching the Observatory. Moreover, in mid-January 1999, following the successful completion of AXAF testing, TRW discovered a problem with circuit boards on some of their spacecraft, including AXAF. The project is currently investigating the extent of the problem on AXAF; however, it appears that the minimum launch delay will be five weeks, or until May 1999. The potential exists for a much longer delay, but at this time the scope of the problems, and the length of the delay, are yet to be determined. NASA will not launch AXAF until we are certain that we have a world-class observatory that has been thoroughly tested and meets all requirements. NASA will inform the Administration and Congress of the new AXAF launch date as soon as possible.

Following launch, the spacecraft will enter a period of checkout, followed by the start of science operations.

In December 1998 NASA announced that AXAF has been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. Chandrasekhar made fundamental contributions to the theory of black holes and other phenomena that the Chandra X-ray Observatory will study. His life and work exemplify the excellence that we hope to achieve with this great observatory

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE INFRARED TELESCOPE FACILITY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
SIRTF development *	70,200	119,700	125,000
ELV (Non-add	--	[8,000]	[23,900]

*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 received the endorsement of the National Research Council's Committee on Astronomy and Astrophysics, satisfy most of the major scientific themes outlined for the original SIRTF mission in the "Bahcall Report" (which judged SIRTF the highest priority major new program for all of U.S. astronomy in the 1990s).

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

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

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

3. Is the mass of the Galaxy hidden in sub-stellar objects and giant planets? SIRTF will search for cold objects with mass less than 0.08 that of the Sun, not massive enough to ignite nuclear reactions, which may contain a significant fraction of the mass of the Galaxy.

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

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

While these scientific objectives drive the mission design, SIRTF's powerful capabilities have the potential to address a wide range of other astronomical investigations, 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 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. The CTA will consist of all of the elements of SIRTF that will operate in space at reduced or cryogenic temperatures, including the telescope, telescope cover, cryostat, and supporting structures and baffles. The cryostat will contain the cold portions of the PI-provided 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. The spacecraft assembly 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 Kelvin, 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 science instruments, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF will be performed by this element.

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

SIRTF is planned for launch on a Delta 7925-H launch vehicle during FY 2002.

SCHEDULE & OUTPUTS

Start Phase C/D Plan: April 1998 Actual: April 1998	Approved by NASA to proceed with detailed design and development.
Critical Design Review Plan: October 1998 Actual: October 1998	The review at the completion of the detailed design demonstrated that the SIRTF design is credible within planned resources, and that it satisfies the science community's expectations.
Instrument deliveries and performance Plan: April 2000	Deliver the Space Infrared Telescope Facility (SIRTF) Infrared Array Camera (IRAC), Multiband Imaging Photometer (MIPS), and Infrared Spectrograph (IRS) instruments during 4/00. The instruments shall perform at their specified levels at delivery.

ACCOMPLISHMENTS AND PLANS

SIRTF proceeded into detailed design and development phase in 1998. Critical Design Review (CDR) was completed in September 1998. SIRTF will complete its spacecraft bus structure by May 1999. Delivery of all of the focal plane arrays will be completed by September 1999. The flight model of the cryostat will be completed by October 1999. Delivery of the instruments will be completed in FY 2000 to enable integration of the Cryo/Telescope Assembly late in the fiscal year.

BASIS OF FY 2000 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Hubble Space Telescope Development...............................	144,900	161,400	140,400

PROGRAM GOALS

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

STRATEGY FOR ACHIEVING GOALS

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

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

The Second HST Servicing Mission occurred in February 1997. The crew accomplished the following tasks: replaced a failed Fine Guidance Sensor (FGS); swapped one of the reel-to-reel tape recorders with a solid-state recorder; and exchanged two of the original instruments (the Goddard High-Resolution Spectrograph and the Faint Object Spectrograph) with two new instruments, the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). In addition to this planned work, astronauts discovered that some of the insulation around the light shield portion of the telescope had degraded and they attached several thermal insulation blankets to correct the problem.

The Third HST Servicing Mission, currently scheduled for late FY 2000, will include a full schedule of astronaut activities to upgrade and maintain the observatory. The mission will install a new scientific instrument, the Advanced Camera for Surveys (ACS), as well as a new flight computer and solar arrays. The final servicing mission in 2003 will install the new Cosmic Origins Spectrograph instrument and perform other maintenance activities to ensure that the spacecraft is in excellent health.

SCHEDULE & OUTPUTS

Ship Advanced Camera to GSFC Plan: July 1998 Actual: November 1998	Allows for final testing prior to shipment to the launch site. Late delivery accommodated within schedule for Third Servicing Mission.
HOST/Cryocooler mission Plan: Oct-Nov 1998 Actual: Oct-Nov 1998	Successfully tested hardware to be installed during the Third HST Servicing Mission in FY 2000.
Observatory Upgrades Plan: May 2000	Successfully install and activate three key HST upgrades during the third servicing mission in FY 2000: flight computer, advanced camera, and solar arrays.

ACCOMPLISHMENTS AND PLANS

Planning and hardware development in preparation for the Third HST Servicing Mission is proceeding well. The Advanced Camera for Surveys (ACS) science instrument has been delivered to GSFC, and testing is ongoing. Meanwhile, a Shuttle flight was conducted in October-November 1998 to test various components that will be installed in 2000. Successfully tested were a new cooling system for the NICMOS instrument that should extend NICMOS's operational life by at least five years, as well as a new Solid State Recorder and a new 486-based computer system.

BASIS OF FY 1998 FUNDING REQUIREMENT

RELATIVITY MISSION

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
GP-B Development *	70,800	57,400	40,500
ELV (Non-add)	[13,500]	[14,800]	[14,800]

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

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

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

STRATEGY FOR ACHIEVING GOALS

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

and, (2) the distortion caused by the movement of the Relativity Mission spacecraft through the Earth's gravitational field south to north, to a level of precision of 0.2 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.) and spacecraft development are conducted at Stanford in collaboration with Lockheed Martin Missiles and Space Palo Alto Research Laboratory (LPARL). Spacecraft development and systems integration will be performed by Lockheed Martin Missiles and Space. Launch is scheduled for October 2000 aboard a Delta II launch vehicle.

SCHEDULE & OUTPUTS

Flight Probe Delivery Plan: September 1997 Current: February, 1998	The flight probe is the interface between the science instrument and the flight dewar. Flight unit delivery will support payload integration. Delay in schedule due to axial lock problem
Flight Probe integrated with Science Instrument Assembly Plan: April 1998 Current: April 1999	Successful integration of the science instrument (comprised of gyroscopes, telescopes, detection electronics, and gas management) with the probe. Schedule delays have resulted from technical problems in various science instruments, subsystems, especially the detector package assembly and acceptance testing of the flight gyroscopes.
Flight Telescope Delivery Plan: February 1998 Current: January 1999	Delivery of the custom, fused-quartz star tracking telescope. Schedule has been delayed principally by numerous development problems with the Detector Package Assembly.
Payload Flight Verification Plan: February 1999 Current: September 1999	Complete the payload (dewar, science instrument, and probe) testing and verification. Schedule delay is driven by later delivery of the science instrument.
Spacecraft Design, Fab, Assy, and Test Plan: March 1999 Current: April 1999	Complete the spacecraft design, fabrication, assembly, and test. Minor delay due to later delivery of some subsystems, including the flight computer, attitude control electronics, and transponder.
Integration and Test Plan: March 2000 Current: September 2000	Complete final integration and test of the Gravity Probe-B science payload. Schedule delay is due to later delivery of the integrated payload as identified above.

Launch Plan: March 2000 Current: October 2000	Launch aboard a Delta II launch vehicle. The launch date changed back to original date due to delays in the payload subsystems including the probe and the science instrument.

ACCOMPLISHMENTS AND PLANS

The Relativity Mission is proceeding toward the original October 2000 launch date. The program had previously been attempting to achieve an earlier launch date, but technical issues have eliminated that possibility. The spacecraft is manifested to launch aboard a Delta II. Among some of the accomplishment in FY 1998, the Critical Design Review of Payload Electronics was completed in November 1997. The Flight Probe for GP-B was delivered for integration on April 1998 and the flight Superconducting Quantum Interference Device (SQUID) packages were delivered in September 1998.

In FY 1999, the program expects to complete the flight telescope, flight electronics boxes and integrated payload testing.

The program was subject to Independent Annual Review and External Independent Readiness Reviews in 1998 and will support like reviews in 1999 and 2000 leading up to final acceptance and launch.

The delay from the early launch in March 2000 to the baseline date in October 2000 has created the potential for significant cost growth. The cost growth is driven by schedule and manpower needs associated with resolving the technical issues that caused the delay. To prevent or mitigate further schedule delays, resources are being shifted from the spacecraft effort, which is well ahead of critical path, to the science instrument and associated electronics, which are on the critical path. The civil service on-site presence at Stanford has been significantly increased to give greater oversight. NASA is continuing to review Relativity Mission funding requirements and will provide necessary notifications when the final decision is made.

BASIS OF FY 2000 FUNDING REQUIREMENT

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
TIMED Development *	64,400	49,300	16,000
ELV (Non-add)	[8,700]	[11,500]	[6,100]

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

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

STRATEGY FOR ACHIEVING GOALS

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

TIMED is scheduled for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission. The program began its 36-month Phase C/D development period in April 1997. TIMED will be a single spacecraft located in a high-inclination, low-Earth orbit with instrumentation to remotely sense the mesosphere/lower thermosphere/ionosphere regions of the Earth's atmosphere. TIMED will carry four instruments: the Solar Extreme ultraviolet Experiment (SEE), the

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

SCHEDULE & OUTPUTS

Begin Spacecraft I&T Plan: January 1999	Spacecraft integration and test in preparation for launch. On schedule.
Completion of Instrument Development Plan: June 1999	Complete delivery of all 4 flight instruments to APL.
Launch Plan: February 2000 Revised: May 2000	TIMED will be delivered on time for launch, within 10% of the planned development budget.

ACCOMPLISHMENTS AND PLANS

A contract for the TIMED development was awarded in the third quarter of FY 1997 to enable full-scale development of the four instruments and the spacecraft. A Preliminary Design Review (PDR) was held in first quarter of 1997, with a Critical Design Review (CDR) in December 1997. Instrument and spacecraft subsystem fabrication started in FY 1998. The spacecraft structure, harness and Integrated Electronics Module (IEM) engineering model were completed in FY 1998. Spacecraft development will begin in FY 1999, with major components to be integrated and tested. All of the instruments are scheduled for delivery by June 1999. TIMED will be completed in early 2000 and will be in storage until March 2000 with launch scheduled for May 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Stratospheric Observatory for Infrared Astronomy............	45,800	58,200	45,100
[Construction of Facilities]	--	[7,300]	--
Total	45,800	58,200	45,100

PROGRAM GOALS

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

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

STRATEGY FOR ACHIEVING GOALS

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

KAO operations were terminated in October 1995; the savings from cessation of KAO operations are an integral element of the funding plan for SOFIA. Development of SOFIA started in FY 1997. In December 1996, NASA selected a team led by the Universities Space Research Association (USRA), Columbia, MD, to acquire, develop and operate SOFIA. The Cost-Plus-Incentive and Award Fee-type contract has a base period for development plus one five-year operations cycle. The contract also contains an option period for one additional five-year operations cycle. SOFIA is expected to operate for at least 20 years. The contract is managed by NASA's Ames Research Center, Mountain View, CA. Other team members include Raytheon Systems Company - Waco, TX ; United Airlines, San Francisco; an alliance of the Astronomical Society of the Pacific and The SETI Institute, both of Mountain View, CA; Sterling Software, Redwood City, CA; and the University of California at Berkeley and Los Angeles. The contract 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 (provided by Germany), test and deliver the flying astronomical observatory to NASA, and provide mission and operations support in approximately five-year increments. USRA's proposal calls for operating the aircraft out of Moffett Federal Airfield, Mountain View, CA, with initial operations starting October 2001. SOFIA funding includes $7.3 million in FY 1999 Construction of Facilities funds for modification of SOFIA ground support facilities at Ames Research Center.

SCHEDULE & OUTPUTS

US System Preliminary Design Review Plan: August 1998 Actual: November 1998	Review of the U.S. contractor's concept for development and integration of the observatory. Slipped due to delays in the development of the German telescope assembly.
Telescope Assembly Critical Design Review Plan: November 1998 Revised: Spring 1999	Formal review of the German contractor's concept for implementation of the telescope assembly. Slipped due to delays in the development of the German telescope assembly.
US System Critical Design Review Plan: September 1999	Formal review of the US concept for implementation of the observatory. NOTE: Planned dates of implementation for this and subsequent milestones are under review as a result of the delay expected in the delivery of the German telescope assembly.
Complete mockup test activity Plan: June 2000	Complete the 747 Section 46 mockup test activity with no functional test discrepancies that would invalidate CDR-level designs and cause significant design rework with attendant cost and schedule impact.

ACCOMPLISHMENTS AND PLANS

The 747 SP aircraft for SOFIA was purchased in early 1997 and is now at the contractor facility in Waco. It has been completely stripped out and undergone a thorough inspection prior to the extensive modification and integration program required to accommodate the German Telescope Assembly.

In FY 1998, the 747 SP aircraft was instrumented and flown from the Waco facility during its baseline flight test phase in order to determine its exact structural and aerodynamic parameters, in addition to the handling characteristics of this specific aircraft, prior to its entering the modification program. This data was also used extensively to validate the wind tunnel and computational aerodynamic models and algorithms during wind tunnel tests at NASA's Ames Research Center at Moffett Field, CA in FY 1998.

Also in FY 1998, a large section of the aft fuselage from a surplus 747 SP was acquired and delivered to Waco via the NASA "SuperGuppy" cargo aircraft to Waco. The section has begun a modification program to serve as a pathfinder to validate the detailed design, fabrication, and integration processes to be used on the SOFIA aircraft.

In Germany, the primary mirror (2.5-meter effective diameter) began an extensive light-weighting process, whereby cells are delicately machined to remove mass from the substrate of the mirror without compromising its precision surface. About three-quarters of the planned mass was removed during the year, on schedule.

Early in FY 1998, the dates for completion of both the German and U.S. preliminary design reviews (PDRs) were delayed from the baseline plans due to unanticipated technical challenges that surfaced for the German Telescope Assembly contractors. These telescope delays affected aircraft-telescope interface design completion, and had a similar delay on the U.S. effort. However, both the U.S. and German PDRs were subsequently held and successfully completed (in early FY 1999) for their respective contributions to this cooperative program.

In FY 1999, as noted above, the U.S. and German PDRs have been completed, and plans are underway to accomplish the Telescope Assembly Critical Design Review (CDR) later in this year. Fabrication and initial integration of key core telescope subsystems will also take place. A major task in FY 1999 will be to re-plan the overall program, to preserve efficiency and recognize the delay in the planned delivery of the German telescope. Also, in FY 1999, modifications of the hangar at Moffett Field, CA will begin, ultimately leading to the Science and Mission Operations Center, the "home" for the SOFIA Observatory once it enters science operations. Finally, wind tunnel testing and aerodynamic analysis of the modified aircraft will be completed.

In FY 2000, subject to details to be worked out as a part of the re-planning mentioned above, it is anticipated that the U.S. systems CDR will be completed, the fuselage section mockup pathfinder work will be completed, and major aspects of the structural modification of the 747 SP will be underway. Our German partners should also be far along in the fabrication and integration of the Telescope Assembly, building up to its delivery to the U.S. in the following year (FY 2001) for integration into the SOFIA aircraft.

BASIS OF FY 2000 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Astro-E	7,100	6,400	
Rosetta	[4,900]	12,500	6,200
Cluster-II	3,300	5,000	1,000
Shuttle/international payloads	7,600	5,000	2,800
Total	18,000	28,900	10,000

PROGRAM GOALS

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

STRATEGY FOR ACHIEVING GOALS

In the FY 1994 appropriation, Congress directed NASA to pursue flight of a GSFC-developed X-ray spectrometer on the Japanese Astro-E mission. NASA 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. Launch is scheduled for February 2000.

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

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

The Shuttle/International Payloads program supports other international and U.S. development projects, including 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) and Planck missions.

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 is scheduled for launch in August 1999 on an Ariane V vehicle, and has an operational 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, electron/positron annihilation, and cyclotron emission/absorption -- taking place under extreme conditions of density, temperature, and magnetic field. U.S. participation consists of co-investigators providing hardware and software components to the spectrometer and imager instruments; a co-investigator for the data center; a mission scientist; and a provision for ground tracking and data collection. Launch is expected in March 2001; INTEGRAL has a design life of two years.

Planck is the third Medium-Sized Mission (M3) of ESA's Horizon 2000 Scientific Programme. It is designed to image the anisotropies of the Cosmic Background Radiation Field over the whole sky, with unprecedented sensitivity and angular resolution. Planck will provide a major source of information to help resolve several cosmological and astrophysical issues by verifying or refuting the assumptions underlying competing theories of the early universe and the origin of cosmic structure. Although formal agreements have not been finalized, NASA expects to contribute hardware elements for the mission in exchange for science participation.

SCHEDULE & OUTPUTS

Astro-E:

Flight model spectrometer delivery to Japan Plan: July 1997 Revised: February 1999	This task concludes the XRS instrument construction phase and begins a period of validation, testing and calibration. Expected to be completed late, with subcomponents delivered to Japan as completed. Late deliveries have been accommodated by the Japanese within their schedule.

Final mirror quadrant delivery Plan: December 1998 Revised: February 1999	Satisfies NASA's commitment to provide the X-ray mirrors for the mission to Japan. Late deliveries have been accommodated by the Japanese within their schedule.
Rosetta:	
Start Phase C/D Plan: January 1999	Start of detailed design and fabrication.
Qual model deliveries Plan: May 2000	The Rosetta project will deliver the electrical qualification models for the four U.S.- provided instruments to ESA in 5/00 for integration with the Rosetta Orbiter.
Cluster-II:	
First flight model instrument set delivered Plan: September 1998 Actual: September 1998	The U.S will provide an identical set of instrument hardware for each of the four Cluster-II spacecraft.
4th/final flight model instrument set delivered Plan: August 1999	On schedule.
Instrument Analysis Software and Verification Plan: FY 2000	Complete development of Cluster-II instrument analysis software for the one U.S. and five U.S.-partnered instruments before launch and, if launch occurs in FY00, activate and verify the Wideband Data (WBD) and U.S. subcomponents after launch.
Other Shuttle/International:	
XMM: deliver RGS FM-2 components Plan: May 1998 Actual: March 1998	Delivery of U.S. Reflection Grating Spectrometer Flight Model-2 components to Germany for calibration testing with the X-ray telescope.
XMM Launch Plan: August 1999 Revised: January 2000	Launch on Ariane-5 ELV. Later launch date set by the Europeans for reasons unrelated to U.S. hardware deliveries.
INTEGRAL Critical Design Review Plan: June 1999	This ESTEC/ESA program review will include the U.S.-provided hardware. On schedule.
INTEGRAL operations readiness	Prepare the INTEGRAL Science Data Center (ISDC) for data archiving and prepare instrument

Plan: FY 2000	analysis software for Spectrometer on INTEGRAL (SPI) instrument within 10% of estimated cost.
Planck cooler test Plan: April 2000	Assemble and successfully test the breadboard cooler for ESA's Planck mission

ACCOMPLISHMENTS AND PLANS

The first quadrant of flight model mirrors for Astro-E was delivered to Japan in December 1997, and the fifth and final mirror will be delivered by February 1999, about two months late. The science instrument hardware has experienced even more serious technical difficulties and delays, resulting in a slight overrun (about 3% to date). The project is still on schedule for a February 2000 launch, but is being threatened by late deliveries of U.S. hardware, which have already required the Japanese to modify their schedule significantly. We will continue to work with our Japanese partners to ensure a successful mission.

Phase C/D development of the U.S. Rosetta instruments will begin in January 1999. Thermal qualification models will be delivered in April 1999, followed by electrical qualification models in February 2000.

Cluster II instrument development activities have progressed very well. Deliveries of the 2nd, 3rd, and 4th Cluster-II flight model sets will occur throughout FY 1999, supporting ESA's June 2000 launch date.

XMM Flight Model-2 RGS components were delivered to Germany ahead of schedule in March 1998. The U.S. will support integration of instruments onto the spacecraft, and spacecraft integration with the launch vehicle, up through planned launch in January 2000.

INTEGRAL engineering model instruments were delivered to ESTEC on schedule in May 1998. Work on the flight model will continue through FY 99; Flight Model delivery is expected in October 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

EXPLORER PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
FUSE	38,100	15,900	--
SWAS, TRACE, WIRE	28,700	6,500	--
IMAGE & MAP	65,200	82,300	42,300
STEDI (SNOE, TERRIER, CATSAT)	1,200	5,500	1,000
HETE-II	7,500	7,200	--
Explorer Planning (All Others)	28,600	78,600	107,700
ELV (Non-add)	[55,800]	[81,700]	[45,800]
*Total	169,300	196,000	151,000

*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 Space Science investigations that can be accommodated with small to mid-sized spacecraft. The program supports investigations in all Space Science 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 missions are therefore subject to the availability of sufficient funding in order to stay within the total program budget. Explorer missions are categorized by size, starting with the largest, Delta-class, moving down through the Medium-class (MIDEX), the Small-class (SMEX) and the University-class (UNEX) missions. As part of NASA's efforts to reduce the cost of Explorer missions, no new Delta-class missions are budgeted. Funding for Explorer mission studies is also provided within the Explorer budget.

Delta Class

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission, previously planned as a Delta-class mission, was restructured in order to reduce costs and accelerate the launch date from CY 2000 to early CY 1999. Although not a MIDEX mission, FUSE can be seen as a transitional step towards the MIDEX program. 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 was selected by JHU as the spacecraft developer. Canada provides the fine error sensor assembly, and France provides holographic gratings. GSFC provides management oversight of this Principal Investigator-managed mission.

Medium Class

The Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in all OSS themes. Plans call for about one MIDEX mission to be launched per year, with life-cycle cost capped at no more than $140 million (FY1998 dollars) each, including the cost of the launch vehicle and mission operations and data analysis.

In March 1996 NASA selected the first two science missions for the MIDEX program, the Microwave Anisotropy Probe (MAP) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. MAP is scheduled for launch in November 2000.

The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute is developing the IMAGE mission for launch in February 2000. The Announcement of Opportunity (AO) for MIDEX 3 & 4 was released in April of 1998 and selections will be made in early CY 1999.

Small Class

The Small Explorer (SMEX) program provides frequent flight opportunities for highly focused and relatively inexpensive missions. Each SMEX mission is expected to cost no more than $71 million (in FY 1998 dollars) for design, development, launch vehicle and operations. The Explorer Program Office at the Goddard Space Flight Center (GSFC) manages mission definition, development, and launch of these SMEX missions.

The Transition Region and Coronal Explorer (TRACE) mission initiated development in October 1994, and was successfully launched in April 1998. 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 Submillimeter Wave Astronomy Satellite (SWAS) mission initiated development in 1991. 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 provided a spectrometer. The launch of the SWAS mission was delayed from January 1997 to December 1998 due to failures of the Orbital Sciences Corporation (OSC) Pegasus launch vehicle and subsequent Pegasus manifest problems. SWAS was successfully launched in December 1998.

The Wide-field Infrared Explorer (WIRE) mission initiated development in October 1994, and is scheduled for launch in early CY 1999. WIRE will detect starburst galaxies, ultraluminous galaxies, and luminous protogalaxies. Major participants in WIRE include Utah State University, Ball Aerospace, Cornell University, California Institute of Technology, and the Jet Propulsion Laboratory.

NASA released a SMEX Announcement of Opportunity (AO) in 1997, and selected the High Energy Solar Spectroscopic Imager (HESSI), being developed by the University of California at Berkeley, and the Galaxy Evolution Explorer (GALEX), being developed by the California Institute of Technology, to be the next Small Explorer missions. HESSI will observe the Sun to study particle acceleration and energy release in solar flares. GALEX will use an ultraviolet telescope during its two-year mission to explore the origin and evolution of galaxies and the origins of stars and heavy elements. GALEX will detect millions of galaxies out to a distance of billions of light years, and will also conduct an all-sky ultraviolet survey. HESSI is scheduled for launch on board a Pegasus ELV in the summer of 2000. GALEX is scheduled for launch in mid-CY 2001.

University Class

University-class Explorer (UNEX) missions enable a higher flight rate to provide the academic community with routine access to space science research. 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. NASA released a UNEX AO in 1998 and selected two new missions, CHIPS and IMEX.

The Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) spacecraft to be developed by the University of California Berkeley, will use an extreme ultraviolet spectrograph during its one-year mission to study the “Local Bubble,” a tenuous cloud of hot gas surrounding our Solar System that extends about 300 light-years from the Sun.

The second mission, the Inner Magnetosphere Explorer (IMEX), to be developed by the University of Minnesota, will study the response of Earth’s Van Allen radiation belts to variations in the solar wind. Future UNEX missions will be capped at $7.5 million in real year dollars for definition, development, launch, operations and data analysis.

The UNEX missions under the Student Explorer Demonstration Initiative (STEDI) include the Student Nitric Oxide Experiment (SNOE), launched in January 1998; the Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS), scheduled for launch during the 2nd Qtr of CY 1999; and the Cooperative Astrophysics and Technology Satellite (CATSAT), with launch expected in 2001.

MISSIONS OF OPPORTUNITY

The Missions of Opportunity (MOpp) were instituted within the Explorer Program as part of the previously mentioned SMEX AO. MOpp are space science investigations, costing no more than $21 million in FY1998 dollars, that are flown as part of a non-NASA space mission. MOpp are conducted on a no exchange of funds basis with the organization sponsoring the mission. OSS intends to solicit proposals for MOpp with all future Explorer AOs. Under the 1997 SMEX AO, the Two Wide-Angle Neutral-Atom Spectrometers (TWINS) investigation was selected as a MOpp. TWINS will enable three-dimensional global visualization of Earth's magnetospheric region, thereby greatly enhancing understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. Instruments for the TWINS mission are being developed by Los Alamos National Laboratory (LANL).

HETE-II

Development is underway for HETE-II, an international (France, Italy and Japan) collaboration to be launched in late 1999. HETE-II will seek to obtain precise positions of gamma-ray bursters and other high-energy transient sources. HETE-II is a replacement for HETE-I, which was launched 100 miles off the coast of Wallops Island, Virginia, on November 4, 1996, but was lost due to launch vehicle third-stage power failures.

SCHEDULE & OUTPUTS

Far Ultraviolet Spectroscopy Explorer (FUSE)

Integration & Test Plan: April 1998 Actual: December 1998	Assemble and test major spacecraft components. Integration completed in August; testing completed December 1998. Late deliveries of several components, particularly the Fine Error Sensors, caused these delays.
Ship to KSC Plan: September 1998 Current: April 1999	Complete spacecraft system-level testing successfully. Move to KSC for integration with Delta II launch vehicle. Slipped due to component I&T problems noted above, and gyro test results suggesting potential lifetime issue, necessitating gyro rework and additional testing.
Launch Plan: October 1998 Current: May 1999	Development delays noted above.

Medium-class Explorer Program

IMAGE	
Complete S/C Environmental Testing Plan: April 1999	Integrate and test major spacecraft subsystems. On schedule.
Delivery, Launch, Cost Plan: February 2000	IMAGE will be delivered for an on-time launch within 10% of the planned development budget.
MAP	
Instrument Delivery Plan: 2nd Qtr. CY 1999	Complete instrument development and ship for integration with the spacecraft. On schedule.
Begin S/C I&T Plan: 3rd Qtr. CY 1999 Actual:	Integrate and test major spacecraft components. On schedule.
Start Environmental Testing Plan: July 2000	Begin system-level environmental testing of the spacecraft.

Small-class Explorer Program

SWAS	
Launch Plan: March 1997 Actual: December 1998	Delayed due to Pegasus launch vehicle availability.
TRACE	
Launch Plan: October 1997 Actual: March 1998	Delayed due to Pegasus launch vehicle availability.
WIRE	
Launch Plan: August 1998 Current: March 1999	Delayed due to Pegasus launch vehicle availability.
HESSI	

Delivery, Launch, Cost Plan: July 2000	The High Energy Solar Spectroscopic Imager will be delivered for an on-time launch, within 10% of the planned development budget.

GALEX

Instrument delivery Plan: July 2000	Deliver the Galaxy Evolution Explorer Science Instrument from JPL to the Space Astrophysics Laboratory at Caltech for science calibration. The instrument will be fully integrated, functionally tested, and environmentally qualified at the time of delivery.

TWINS

Component deliveries Plan: March 2000	Deliver to the Los Alamos National Laboratory (LANL) all components for system integration and testing of the first flight system for the Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) mission.

University-class Explorer Program

SNOE

Launched Actual: January 22, 1998	Completed development and launched spacecraft into orbit. Spacecraft is performing well.

TERRIERS

Launch Plan: April 1999	Begin the study a number of ionospheric and thermospheric phenomena, and test the utility of long term solar EUV (extreme ultraviolet) irradiance measurements.

CATSAT

Launch Plan: 3rd Qtr FY 1999 Revised: TBD	Complete development and launch spacecraft into orbit. Delayed due to uncertain launch accommodations.

HETE-II

Launch Plan: December 1999	Complete development and launch spacecraft into orbit on an Ultra-Lite Class ELV (half Pegasus). On schedule.

AO Activities

Release of UNEX AO Plan: 2nd Qtr FY 1997 Actual: January 1998	Release an Announcement of Opportunity (AO) for the first round of UNEX missions. Delayed in getting inputs from industry/potential bidders, and implementing lessons learned from the SMEX and MIDEX AO.
Release MIDEX AO Plan: 4th Qtr. FY 1998 Actual: March 1998	Release AO to industry.
Complete UNEX selection Plan: 4th Qtr FY 1997 Actual: September 1998	Select the first round of UNEX missions and initiate development activities. Delayed with delayed release of AO.
MIDEX Selection Plan: 4th Qtr. FY 1999 Actual: January 1999	Mission selection, and initiate concept studies.
Release SMEX AO to industry Plan: 3rd Qtr FY 1999	Release the final AO to industry. On schedule.
SMEX AO Selection Plan: 1st Qtr FY 2000	Missions selection, leading to concept studies.
FY 2000 goals	Select two Small Explorer (SMEX) missions and release a University Explorer (UNEX) Announcement of Opportunity (AO).

ACCOMPLISHMENTS AND PLANS

The Explorers Program successfully launched two missions during FY 1998. The Student Explorer Demonstration Initiative (STEDI) launched the Student Nitric Oxide Explorer (SNOE) in January and the SMEX Project launched the Transition Region and Coronal Explorer (TRACE) in April. The FUSE observatory finished integration and entered its critical environmental test program. Spacecraft component and instrument development continued on the IMAGE and MAP projects. The AO for MIDEX's 3 and 4 was released in April. Testing was completed on the SMEX project's SWAS and WIRE missions. Also the HESSI and GALEX missions were selected. The TWINS mission was selected as a Mission of Opportunity (MOpp). The STEDI missions; TERRIERS and CATSAT continued development. The AO for UNEX 1 and 2 was released and the CHIPS and IMEX missions were selected. Their concept studies are underway. The Polarimeter for Low Energy X-ray Astrophysical Sources (PLEXAS) was also selected under this AO as a technology initiative at the Harvard-Smithsonian Center for Astrophysics.

The Explorers Program is planning to launch four missions in FY 1999. The SWAS mission was successfully launched in December 1998. The WIRE, TERRIERS, and FUSE missions are scheduled for launch in February, April and May, respectively. Development continues on the IMAGE, MAP, HESSI, GALEX, CHIPS, and IMEX missions. Also four MIDEX's will be selected for Phase A studies which will lead to the down-selection of two new MIDEX missions for developments during the latter part of the fiscal year.

The FY2000 Explorers budget continues to support a full range of mission activities across the various classes of missions. MIDEX activities will include the IMAGE launch scheduled for February 2000. MAP will complete system-level testing and be ready for the November 2000 scheduled launch. Two new MIDEX missions, selected in FY 1999, are expected to complete the formulation phase and enter into development. SMEX activities include the HESSI launch, scheduled for July 2000, and the GALEX science instrument delivery from Jet Propulsion Laboratory (JPL) to the California Institute of Technology. Two new SMEX missions will be selected. The University-class Explorer (UNEX) budget will support the continued development of the CHIPS and IMEX missions, and the launch and early operations of the Cooperative Astrophysics and Technology Satellite (CATSAT). Funding will also be provided to continue MO&DA activities for the SNOE and Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS) missions. Development will continue on the two missions to be selected in FY 1999. Missions of Opportunity (MOpp) include a launch for High Energy Transient Explorer (HETE)-II and continued development of the Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS) mission. Potential new MOpps selected through current or FY 1999 AOs will also be supported.

BASIS OF FY 2000 FUNDING REQUIREMENT

DISCOVERY PROGRAM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Lunar Prospector *	400	--	--
Stardust *	56,200	22,300	--
Genesis *	29,900	82,900	50,200
CONTOUR *	--	--	51,800
Future Missions	13,500	19,700	78,500
ELV (Non-add)	[23,500]	[30,300]	[42,900]
Total	100,000	124,900	180,500

*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 Lunar Prospector mission was selected as the third Discovery mission in FY 1995 with mission management from the NASA Ames Research Center. The spacecraft was launched successfully on January 6, 1998. Lockheed Martin supplied the launch, spacecraft and instruments, and is providing operations support. Tracking and communications support is 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.

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory, and was approved for implementation in October, 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. Stardust will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, Stardust 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 a Med-Lite version of the Delta II expendable launch vehicle in February 1999, to rendezvous with the comet in January 2004 and return the samples to Earth in January 2006.

In October 1997 NASA selected the next two Discovery missions: Genesis and the Comet Nucleus Tour (CONTOUR). The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. The mission is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA. JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, Genesis will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

CONTOUR's goals are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future “new” comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management will be provided by the Johns Hopkins University Applied Physics Laboratory of Laurel, MD. Launch is expected in June 2002.

Total Discovery mission development is managed within an approved 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 Future Missions budget.

SCHEDULE & OUTPUTS

Stardust

Start Spacecraft Assembly/Test Plan: January 1998 Actual: January 1998	Begin to integrate major components of the spacecraft onto the spacecraft structure.
Start environmental tests Plan: June 1998 Actual: July 1998	Begin tests to demonstrate that the assembled spacecraft can withstand the launch and space environments. Started slightly late; no impact to launch – spacecraft shipped on schedule to KSC November 11.
Launch Plan: February 1999	On schedule.

Genesis

Preliminary Design Review Plan: August 1998 Actual: July 1998	Confirmation that the mission is ready to proceed to Phase C/D.
Critical Design Review Plan: May 1999	Confirmation that the mission design is sound. On schedule.
Start functional testing Plan: November 1999	Complete Genesis spacecraft assembly and start functional testing in 11/99.

CONTOUR

Phase B Study Start Plan: October 1998 Revised: April 1999	Start of detailed design studies. Revision does not impact launch schedule.
Instrument and Spacecraft Development Plan: FY 2000	Successfully complete the bread-board of the imager instrument for CONTOUR and award the contract for the propulsion system after a PDR that confirms the design and maintains 15% margins for mass and power.

Announcements of Opportunity (AOs)

Release Final AO Plan: 3rd Qtr FY 1998 Actual: March 1998	Release an Announcement of Opportunity (AO) for the next discovery mission(s). Completed ahead of schedule.
Step 2 Selection Plan: 3rd Qtr FY 1999	Phase 2 selection leading to Phase B studies. On schedule.
FY 2000 Goal	Release an AO for the next Discovery mission.

ACCOMPLISHMENTS AND PLANS

Assembly and test of the Stardust spacecraft components was completed on time, and the spacecraft was shipped to KSC in preparation for launch in February 1999.

The Genesis mission is off to a fast start, as required to meet its planned launch in January 2001. Phase C/D activities began in August 1998, following completion of the Preliminary Design Review. During FY 1999, detailed design activities will continue, leading to the Critical Design Review in May 1999. System level integration and test activities will occur during FY 2000

The CONTOUR mission will start Phase B in FY 1999. The mission plans for twelve months of Phase B studies, followed by the start of Phase C/D development early in FY 2000.

A draft Announcement of Opportunity was released for comment in January 1998, and the final AO was released in March 1998. In November 1998, five candidate Discovery missions were selected for further study, including missions to Mercury, Venus, Mars, Jupiter, and a comet. Also selected for development was a proposal to build hardware for the European Space Agency's Mars Express mission, which will fly in 2003. Final proposals will be submitted in March, leading to selection of the next Discovery mission(s) this summer.

BASIS OF FY 2000 FUNDING REQUIREMENT

MARS SURVEYOR PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
98 Orbiter and Lander..	79,600	22,000	--
01 Orbiter and Lander	71,200	150,700	126,800
Mars Network	--	--	4,100
Micromissions	--	--	5,000
Future Missions	37,100	55,700	114,800
ELV (Non-add)	[42,700]	[48,700]	[40,900]
Total	187,900	228,400	250,700

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the Mars Surveyor Program is to further our understanding of the biological potential and possible biological history of Mars, and to search for indicators of past and/or present life there. The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. Missions are planned for launch at every launch opportunity; opportunities occur about every 26 months due to the orbital periods of Earth and Mars. In the near term, missions may either orbit Mars to perform mapping of the planet and its space environment, or actually land on the planet to perform science from the surface. A long-term goal is to acquire and return the first carefully selected sample cache by 2008 and at least three sets of samples from diverse sites by 2012. Earlier missions will facilitate this long-range goal by identifying those areas of Mars 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 that will obtain much of the data that would have been obtained from the Mars Observer mission. The orbiter carries a science payload, comprised of 6 of 8 spare Mars Observer instruments, aboard a small, industry-developed spacecraft. MGS was launched in November 1996 aboard a Delta II launch vehicle and placed on a trajectory to Mars. The spacecraft arrived at Mars in September 1997. The spacecraft will use aerobraking to arrive at its final mapping orbit in January 1999, and full mapping operations will begin in March 1999. 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. The Mars Climate Orbiter successfully launched in December 1998, and the Mars Polar Lander successfully launched in January 1999. These missions will be followed by two launches in the March/April 2001 opportunity, and launches in the 2003 and 2005 opportunities.

The 2001 and subsequent missions were the subject of detailed reviews by independent teams during 1998. As a result, the design of the 2001 mission, and the architecture for the 2003 and follow-on missions, were revised to improve the likelihood of achieving the program's scientific goals within available resources.

The Mars 2001orbiter will perform global mapping of the surface elemental composition and high-resolution mapping of surface minerology, and will also provide high-spatial-resolution surface morphology. The lander will analyze and document surface soil composition, and will deploy a Sojourner-class rover. The mission will also collect data and demonstrate technologies critical to initiating the exploration of Mars by humans, thus meeting objectives set forth by the Human Exploration and Development of Space (HEDS) office.

The Mars 2003 mission will include Mars Express (built by ESA/ASI), which will perform global mapping and will provide communication capability that is expected to be compatible with Mars 2001. The Mars 2003 lander and the sampling rover will acquire samples that will be placed into orbit via a Mars Ascent Vehicle for future retrieval (Mars 2005 mission). The Mars 2003 mission will complete all the initial HEDS objectives for Mars Surveyor.

Funding for mission studies and for the technology activities that support the Mars Surveyor program are highly specific to this mission series; therefore, funding for these items is included in the Mars Surveyor budget.

Two new program elements are funded in the Mars Surveyor program beginning in FY 2000: Mars Network and Micromissions. The Mars Network will develop a communications capability to provide a substantial increase in bandwidth and connectivity from Mars to Earth. Although the specific missions and infrastructure needed to create this capability remain to be evaluated, one possible scenario is the development of one or more small relay satellites in orbit around Mars. These satellites could fulfill several user needs, such as increased connectivity for surface rover operations, high-sensitivity relay capability for small, energy-constrained microlanders, and increased data return rates for science and public outreach. The Mars Surveyor architecture review highlighted improved communications capability as the highest leverage augmentation that could be added to the program.

Mars Micromissions will provide a low-cost capability for delivering small payloads to Mars. For example, small "piggyback" spacecraft can be placed in a geosynchronous transfer orbit by an Ariane-5 expendable launch vehicle and then travel independently to Mars. Each of these competitively selected Principle Investigator class missions will deliver up to a 50-kilogram science payload to Mars to collect high-priority global scientific data. NASA, the French space agency CNES, and Arianespace will work together to establish micromissions as an important element of Mars exploration and infrastructure. The first micromission launch opportunity is planned for 2003. One of the leading concepts currently under review for this mission is a remotely piloted aircraft to provide enhanced mobility for Mars investigations.

SCHEDULE & OUTPUTS

1998 Mars Surveyor Orbiter and Lander

Start Orbiter environmental tests Plan: March 1998 Actual: March 1998	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. Completed on schedule.
Start Lander environmental tests Plan: January 1998 Actual: January 1998	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. Completed on schedule.
Ship Orbiter spacecraft Plan: August 1998 Actual: September 1998	Ship to the launch site. Slip had no impact.
Ship Lander Spacecraft Plan: October 1998 Actual: October 1998	Completed on schedule.
Launch Orbiter Plan: December 1998 Actual: December 1998	Launched on schedule.
Launch Lander Plan: January 1999 Actual: January 1999	Launched on schedule.

2001 Mars Surveyor Orbiter and Lander

Payload Confirmation Review Plan: 3rd Qtr 1998 Actual: 1st Qtr FY 1999	Confirm that the payload is sufficiently defined to move into full-scale development. Slip will not impact launch schedule.
Complete Phase B & start C/D Plan: 3rd Qtr FY 1998 Actual: 1st Qtr FY 1999	Complete definition study and initiate the development effort. Slip will not impact launch schedule.

Preliminary Design Review Plan: 3rd Qtr FY 1998 Actual: 1st Qtr FY 1999	Confirm that the science goals and objectives are achievable within Mission Design. Slip will not impact launch schedule.
Critical Design Review Plan: 2nd Qtr FY 1999 Current: 2nd Qtr FY 1999	Confirmation that the design is sufficient to move into full-scale development. On schedule.
Orbiter and Lander ATLO Start Plan: 1st Qtr FY 2000 Current: 1st Qtr FY 2000	Begin Assembly, Test and Launch Operations (ATLO) by integrating major components of the spacecraft into the spacecraft structure.
Orbiter & Lander Science Instr. Plan: 3rd Qtr FY 2000	Deliver Mars 2001 Orbiter and Lander science instruments that meet capability requirements. Pre-launch Gamma Ray Spectrometer (GRS) tests shall determine abundances in known calibration sources to 10% accuracy.
Ship Orbiter Plan: 1st Qtr FY 2001 Current: 2nd Otr FY 2001	Ship to VAFB launch site.
Ship Lander Plan: 2nd Qtr FY 2001 Current: 2nd Qtr FY 2001	Ship to KSC launch site.
Orbiter Launch Plan: March FY 2001 Current: March FY 2001	Launch on schedule
Lander Launch Plan: April FY 2001 Current: April FY 2001	Launch on schedule
Future Mars Surveyor Missions Plan: FY 2000	Assuming the Mars Surveyor Program architecture is confirmed: meet the milestones for the Mars 2003 instrument selection and initiate implementation of the lander mission. Deliver engineering models of the radio frequency subsystem and antennae for the radar sounder instrument to ESA (if ESA approves the Mars Express mission), and select contractors for major system elements of the Mars Surveyor 2005 mission.

ACCOMPLISHMENTS AND PLANS

The Mars Surveyor 98 mission, an orbiter and a lander, launched in December 1998 and in January 1999, respectively. For the Mars 2001 mission, Lockheed-Martin Aerospace, Denver, was selected as the spacecraft development contractor. The Mars 2001 Orbiter will include Gamma Ray Spectrometer (GRS), Thermal Emission Imaging System (THEMIS), and Mars Radiation Environment Experiment (MARIE). The Mars 2001 Lander will include a Pathfinder/Sojourner-type rover, as well as the Athena Precursor Experiment (APEX), Mars Descent Imager (MARDI), Mars Environmental Compatibility Assessment (MECA), Mars ISPP (In-situ Propellant Production) Precursor (MIP) and a copy of the MARIE experiment also found on the Orbiter. This instrument complement meets the science requirements of the Office of Space Science, the Office of Human Spaceflight, and the Office of Life and Microgravity Sciences and Applications. The spacecraft Preliminary Design Review took place in October 1998, with the Critical Design Review to take place in April 1999. The assembly and testing for the Lander and the Orbiter will begin in October 1999 and January 2000, respectively. The Orbiter and Lander are scheduled to launch in March and April of 2001, respectively.

A Mars Exploration Program Architecture Team was set up during the 3rd Qtr of FY 1998 to develop an architecture for the next decade (2001-2011) that will: achieve significant advances toward understanding the biological history of Mars; search for evidence of past and present life; and prepare the technological and scientific groundwork for Mars exploration in the following decade. The final recommendation is expected 2nd Qtr. 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
HST operations	2,300	2,100	2,100
Other mission operations	136,400	104,200	83,200
Total	138,700	106,300	85,300

PROGRAM GOALS

The goal of the Mission Operations program is to maximize the scientific return from NASA's investment in spacecraft and other data collection sources. The Mission Operations effort is fundamental to achieving the goals of the Office of Space Science program because it funds the operations of the data collecting hardware that produces scientific discoveries. Funding supports satellite operations during the performance of the core missions, plus extended operations of selected spacecraft.

STRATEGY FOR ACHIEVING GOALS AND SCHEDULE & OUTPUTS

The Mission Operations program is working to dramatically reduce costs while preserving, to the greatest extent possible, science output. To do so, it will accept prudent risk, explore new conceptual approaches, streamline management and make other changes to enhance efficiency and effectiveness. The following is a comprehensive list of all Space Science spacecraft that are, or are expected to be, operational at any time between January 1999 and September 2000.

Advanced Composition Explorer (launched August 25, 1997; expected operations beyond FY 2000)
ACE is measuring the composition of the particles streaming from the Sun, as well as high-energy galactic cosmic rays.

> FY 2000 performance: ACE will measure the composition and energy spectra of heavy nuclei in at least eight solar energetic particle events; maintain real-time solar wind data transmissions at least 90% of the time; measure the isotopic composition of a majority of the "primary" galactic cosmic ray elements from carbon to zinc; and provide browse parameters within three days for 90% of the year.

Advanced Spacecraft for Cosmology Astrophysics (launched February 20, 1993; expected operations beyond FY 2000)
ASCA is Japan's fourth cosmic X-ray astronomy mission, and the second for which the United States provided part of the scientific payload.

Advanced X-ray Astrophysics Facility (launch no earlier than May, 1999; expected operations through ~ FY 2009)

The AXAF mission operations budget includes support for the pre-launch development of the AXAF ground system. Post-launch AXAF operations will be conducted from a control center at the AXAF Science Center (ASC) in Boston, developed by the Massachusetts Institute of Technology.

FY 2000 performance: The AXAF instruments will meet nominal performance expectations, and science data will be taken with 70% efficiency with at least 90% of science data recovered on the ground.

Astro-E (launch scheduled February 2000; expected operations beyond FY 2000)
Astro-E 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

FY 2000 performance: If launched, activate the X-ray Spectrometer (XRS) and X-ray Imaging Spectrometer (XIS) instruments on the Japanese Astro-E spacecraft after launch and collect at least 90% of the XRS and XIS data.

Cassini (launched October 15, 1997; expected operations through ~ 2008)
Cassini will conduct a detailed exploration of the Saturnian system including: 1) the study of Saturn's atmosphere, rings and magnetosphere; 2) remote and in-situ study of Saturn's largest moon, Titan; 3) the study of Saturn's other icy moons; and 4) a Jupiter flyby to expand our knowledge of the Jovian System. Cassini will arrive at Saturn in 2004. Proper trajectory is ensured through tracking and targeting maneuvers, and the health of science instruments is maintained by periodic checkouts.

FY 2000 performance: Continue Cassini operations during the quiescent cruise phase without major anomalies, conduct planning for the Jupiter gravity-assist flyby, and explore early science data collection opportunities. The following in-flight activities will be completed: Instrument Checkout#2; uplink Articulation & Attitude Control Subsystem (AACS) software update with Reaction Wheel Authority capability; Command & Data Subsystem Version 8; and Saturn Tour designs for selection by the Program Science Group.

Compton Gamma-Ray Observatory (CGRO) (launched April 5, 1991; expected operations beyond FY 2000)
CGRO is the second of NASA's Great Observatories. It has a diverse scientific agenda, including studies of very energetic celestial phenomena: solar flares, cosmic gamma-ray bursts, pulsars, nova and supernova explosions, accreting black holes of stellar dimensions, quasar emission, and interactions of cosmic rays with the interstellar medium.

FY 2000 performance: Continue to operate those instruments not dependent on expended consumables (Oriented Scintillation Spectrometer Experiment, OSSE; Burst and Transient Source Experiment, BATSE; and Imaging Compton Telescope, COMPTEL) at an average efficiency of at least 60%.

Deep Space 1 (launched October 24, 1998; expected operations beyond FY 2000)
During its two-year primary mission, DS1 will test 12 revolutionary technologies destined for future missions. The new technologies on board the DS1 spacecraft will be proven in arduous spaceflight conditions, so that 21st-century missions can use them with confidence. The DS1 spacecraft will fly by and gather data about an asteroid, and then if the mission is extended by a year, a comet. Heralding future solar system missions, DS1 is the first to use high-performance, solar electric ion propulsion.

Deep Space 2 (launched January 3, 1999 ; expected operations through December 1999)
In December 1999, two basketball-sized aeroshells will crash onto the Martian surface. Each aeroshell will shatter on impact, releasing a miniature two-piece science probe that will punch into the soil to a depth of up to 1 meter. The microprobes' primary science goal is to determine if water ice is present in the Martian subsurface - an important clue in the puzzle of whether life exists, or ever existed, on Mars. The tiny science stations will also measure temperature and monitor local Martian weather.

Extreme Ultraviolet Explorer (launched June 7, 1992; expected operations through September 1999)
EUVE is studying the sky at wavelengths once believed to be completely absorbed by the thin gas between the stars.

Fast Auroral Snapshot (FAST) (launched August 21, 1996; expected operations beyond FY 2000)
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.

> FY 2000 performance: FAST shall return simultaneous data from high-latitude, low-altitude magnetosphere locations in the Sun-Earth connected system through solar maximum at the required resolution and accuracy with at least 85% efficiency. Data are used in conjunction with data from ISTP and TIMED.

Far Ultraviolet Spectroscopic Explorer (FUSE) (launch scheduled May 1999; expected operations beyond FY 2000)
FUSE will conduct high-resolution spectroscopy in the far ultraviolet region.

> FY 2000 performance: The three-year FUSE mission will complete at least one third of the observations needed for its minimum science program with 6 of the 8 instrument performance parameters being met.

Galileo (launched October 18, 1989; expected operations through December 1999)
Galileo is executing a series of close flybys of Jupiter and its moons, studying surface properties, gravity fields and magnetic fields, and characterizing the magnetospheric environment of Jupiter and the circulation of its Great Red Spot. In December 1997, the program began the Galileo Europa Mission (GEM), a detailed study of Jupiter’s ice-covered moon running through 1999.

> FY 2000 performance: Recover at least 90% of playback data from at least 1 Galileo fly-by of Io.

High Energy Solar Spectroscopic Imager (launch scheduled July 2000, expected operations beyond FY 2000)
HESSI will observe the Sun to study particle acceleration and energy release in solar flares.

> FY 2000 performance: Assuming launch and normal checkout, HESSI operations will return data to achieve at least the primary science objectives, with at least 80% coverage of the time allowed by orbit.

Highly Advanced Laboratory for Communications and Astronomy (launched February 12, 1997; expected operations beyond FY 2000)
HALCA is led by Japan's Institute of Space and Astronautical Science. The project allows imaging of astronomical radio sources with a signficantly improved resolution over ground-only observations. The JPL VLBI project provides support for the U.S. tracking stations associated with HALCA, coordinates U.S. science efforts together with the National Radio Observatory (NRAO), and ensures the delivery of high-quality science data to successful U.S. proposers.

Hubble Space Telescope (launched April 25, 1990; expected operations through ~2010)
HST science operations are carried out through an independent HST Science Institute, which operates under a long-term contract with NASA. Satellite operations, including telemetry, flight operations and initial science data transcription, are performed on-site at Goddard Space Flight Center under separate contract. While NASA retains operational responsibility for the observatory, the Science Institute plans, manages, and schedules the scientific operations.

> FY 2000 performance: Maintain an average HST on-target pointing efficiency of 35% during FY00 operations before they are interrupted for the third servicing mission, presently scheduled for May 2000.

Imager for Magnetopause-to-Aurora Global Exploration (launch scheduled February 2000, expected operations beyond FY 2000)
IMAGE will study the global response of the Earth's magnetosphere to the changes in the solar wind.

> FY 2000 performance: If launched, IMAGE will acquire critical measurements at minute time scales, returning 85% real-time coverage of the Earth’s magnetospheric changes.

International Solar-Terrestrial Physics (ISTP)
Geotail (launched July 24, 1992; expected operations beyond FY 2000)
Wind (launched November 1, 1994; expected operations beyond FY 2000)
Polar (launched February 24, 1996; expected operations beyond FY 2000)
Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995; expected operations beyond FY 2000)
Wind, Polar, SOHO, and Geotail are the core spacecraft of the ISTP program. Wind measures the energy, mass, and momentum that the solar wind delivers to the Earth’s magnetosphere. Wind also carries a gamma ray instrument, the first Russian instrument ever to be flown on a U.S. spacecraft. Polar provides dramatic images of the aurora and complementary measurements to provide a direct measure of the energy and mass deposited from the solar wind into the polar ionosphere and upper atmosphere. SOHO studies the solar interior by measuring the seismic activity on the surface; SOHO also investigates the hot

outer atmosphere of the Sun that generates the variable solar wind 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 day side of the Earth.

FY 2000 performance: Collect 85% of data acquired from the ISTP spacecraft; successfully execute the WIND trajectory plan.

Interplanetary Monitoring Platform-8 (launched October 26, 1973; expected operations beyond FY 2000)
IMP-8 performs near-continuous studies of the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

FY 2000 performance: Collect and process data from the Interplanetary Monitoring Platform, making data from at least 6 instruments available within 15 months, and the magnetic field and plasma data available within 2 months

Lunar Prospector (launched January 6, 1998; expected operations through August 1999)
Beginning in November 1998, the orbit of the spacecraft was lowered to about 30 miles above the Moon's surface in order to maximize its scientific return during the final months of operation.

Mars Climate Orbiter (launched December 11, 1998; expected operations beyond FY 2000)
Upon arrival at Mars in September 1999, MCO will use a series of aerobraking maneuvers to achieve a stable orbit, and then use atmospheric instruments and cameras to provide detailed information about the surface and climate of Mars.

FY 2000 performance: In May 2000 MCO will aerobrake from its initial insertion orbit into a near-polar, sun-synchronous, approximately 400km circular orbit, and will initiate mapping operations.

Mars Global Surveyor (launched November 7, 1996; expected operations beyond FY 2000)
MGS will return an unprecedented amount of data regarding Mars' surface features, atmosphere, and magnetic properties. The spacecraft reached Mars in September 1997 and has begun the aerobraking maneuvers to achieve its desired mapping orbit in March 1999, about one year later than planned due to unanticipated deflections in one of the solar array panels. No loss of science is anticipated.

FY 2000 performance: Acquire 70% of science data available, conduct at least two 5-day atmospheric mapping campaigns, and relay to Earth at least 70% of data transmitted at adequate signal levels by the DS2 Mars microprobes.

Mars Polar Lander (launched January 3, 1999; expected operations through February 2000)
In December 1999 MPL will soft land, under propulsive power, near the edges of the South Polar ice cap on Mars. Since it lands in the Martian summertime, only remnants of the cap may be observed. The lander is equipped with cameras, a robotic arm and instruments to measure the Martian soil composition.

FY 2000 performance: In December 1999 MPL will successfully land on Mars and operate its science instruments for the 80-day primary mission with at least 75% of planned science data returned.

Near Earth Asteroid Rendezvous (launched February 17, 1996; expected operations beyond FY 2000)
NEAR flew by Earth for its final gravity assist in January 1998, and will arrive at its primary target (the asteroid 433 Eros) in February 2000. Originally scheduled for Eros rendezvous in February 1999, the start of prime science operations has been delayed by a premature cut-off during the first orbit insertion engine firing in December 1998.

FY 2000 performance: NEAR will successfully orbit 433 Eros and meet primary scientific objectives while not exceeding projected mission cost.

Nozomi (launched July 3, 1998; expected operations beyond FY 2000)
NASA provided a Neutral Mass Spectrometer to the Japanese Institute of Space and Astronautical Science (ISAS), for launch to Mars aboard the Nozomi spacecraft. The project objective is to study the structure and dynamics of the atmosphere and ionosphere of Mars, including any interactions with the solar wind.

Rossi X-ray Timing Explorer (launched December 30, 1995; expected operations beyond FY 2000)
RXTE uses three instruments to conduct timing studies of astronomical X-ray sources.

FY 2000 performance: Operate at least three of the five instruments at an efficiency of 45% with 95% data recovery. All Sky Monitor data will be posted on the web within 7 days, and Proportional Counter Array and High-Energy X-ray Timing Experiment data released within 60 days.

Solar Anomalous and Magnetospheric Particle Explorer (launched July 3, 1992; expected operations beyond FY 2000)
SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

FY 2000 performance: Obtain at least 60% data coverage from at least three of SAMPEX's four instruments.

Stardust (launch scheduled for February 1999; expected sample return to Earth in 2006)
Stardust will perform activities in support of the five-year cruise to rendezvous with Comet Wild-2.

FY 2000 performance: Continue cruise operations without major anomalies and perform interstellar dust collection for at least 36 days.

Student Nitric Oxide Experiment (launched February 25, 1998; operations expected through April 1999)
SNOE is a small scientific satellite investigating the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE was designed and built, and is being operated, entirely at the University of Colorado at Boulder.

Submillimeter Wave Astronomy Satellite (launched December 5, 1998; expected operations through January 2000)

SWAS studies the chemical composition, energy balance and structure of interstellar clouds and the processes that lead to the formation of stars and planets.

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (launch scheduled May 2000; expected operations beyond FY 2000)
TIMED will explore the Earth's Mesosphere and Lower Thermosphere (60-180 kilometers), the least explored and understood region of our atmosphere.

FY 2000 performance: If successfully launched, TIMED will acquire global data in the Mesosphere Lower Thermosphere/Ionosphere region globally (all latitudes) for at least 90 days at the required spatial resolution, coverage, accuracy and for all local solar times.

Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (launch scheduled April 1999; operations expected through April 2000)
TERRIERS will study a number of ionospheric and thermospheric phenomena, and will test the utility of long term solar EUV (extreme ultraviolet) irradiance measurements. TERRIERS is a Boston University student satellite project selected for the Student Explorer Demonstration Initiative program (STEDI).

Transition Region and Coronal Explorer (launched April 1, 1998; expected operations through April 2000)
TRACE observes the effects of the emergence of magnetic flux from deep inside the Sun to the outer corona with high resolution.

FY 2000 performance: Collect pixel-limited images in all TRACE wavelength bands, operating 24-hour schedules for sustained periods over 8 months. TRACE will operate with Yohkoh, HESSI and ground based observatories as a coordinated system to obtain both images and spectral data on the quiet Sun, sunspots, and active solar regions.

Ulysses (launched October 6, 1990; expected operations beyond FY 2000)
Ulysses is currently studying the heliospheric environment out to the orbit of Jupiter by measuring the interplanetary medium and solar wind as a function of heliographic latitude.

FY 2000 performance: Capture at least 90% of available science data, the only data observed from out-of-the-ecliptic plane.

Voyager Interstellar Mission (Voyager 1 launched September 5, 1977; Voyager 2 launched August 20, 1977; expected operations beyond FY 2000)
Voyager 1 and 2 are continuing to probe the outer heliosphere and look for the heliospheric boundary with interstellar space as they travel beyond the planets.

FY 2000 performance: Average 12 hours of Voyager Interstellar Mission data capture per day per spacecraft to characterize the heliosphere and the heliospheric processes at work in the outer solar system as well as the transition from the solar system to interstellar space

Yohkoh (launched August 31, 1991; expected operations beyond FY 2000)
Yohkoh, a cooperative program with the Japanese, gathers X-ray and spectroscopic data on solar flares and the corona.

FY 2000 performance: Acquire calibrated observational data from the Japanese Yohkoh high-energy solar physics mission (including the U.S.-provided Soft X-ray Telescope (SXT)) for at least 75% of the time permitted by tracking coverage.

ACCOMPLISHMENTS AND PLANS

Space Science continues to make progress in lowering mission operations costs while preserving the science return from operating missions. The program is utilizing the savings, and seeking additional cost reductions, in order to sustain operations of ongoing missions as long as is merited by the science return. The science community both inside and outside of NASA regularly reviews the mission operations program to ensure that only the missions with the highest science return are funded. In addition, we are launching smaller spacecraft, and engaging in more international collaborations. As a result, NASA expects to be able to support an increasing number of operational spacecraft through FY 2000 despite a smaller MO budget. In total, we will have about 34 operational Space Science spacecraft at the end of FY 2000, compared to 18 at the beginning of FY 1995. As of the end of January 1999, we have 27 operational missions (29 spacecraft). Missions expected to begin operations before the end of FY 2000 include Stardust (2/99), WIRE (2/99), TERRIERS (4/99), AXAF (4/99), FUSE (5/99), HETE-II (11/99), XMM (1/00), IMAGE (2/00), Astro-E (2/00), TIMED (5/00), Cluster-II (6/00), and HESSI (7/00).

BASIS OF FY 2000 FUNDING REQUIREMENT

SUPPORTING RESEARCH AND TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Supporting Research and Technology	894,000	945,200	1,152,100
Technology Program	469,000	484,900	642,600
Core Program	189,900	207,000	259,000
Space Science Technology...	63,600	56,700	96,900
Cross-Enterprise Technology	126,300	150,300	162,100
Focused Programs	200,000	251,500	367,500
[Construction of Facilities	--	[2,500]	[2,500]
Flight Validation (New Millennium Program.................	79,100	26,400	16,100
Research Program	386,600	417,200	472,000
Research and Analysis	137,900	194,200	182,200
Data Analysis	248,700	223,000	289,800
Suborbital*..	38,400	43,100	37,500
ELV (Non-add)	[32,800]	[9,500]	[12,500]

* The Suborbital program, while included in the SR&T budget, is discussed in a separate section, next under.

PROGRAM GOALS

OVERALL SUPPORTING RESEARCH AND TECHNOLOGY

The Space Science Enterprise's Supporting Research and Technology program is comprised of three major components: the Technology program, the Space Science Research program (consisting of Research and Analysis and Data Analysis) and the Suborbital program. These three elements focus on the activities that occur both before and after space flight mission development and operations. The Technology and Research programs are discussed in this section: Suborbital activities are discussed in the next section. The proper levels of investment in technology, research and suborbital programs are essential to obtaining the high-value scientific results that will enable the Space Science Enterprise to fulfill its mission: to solve the mysteries of the universe including its origins and destiny, explore the solar system, discover planets around other stars, and search for life beyond Earth.

TECHNOLOGY PROGRAM

The goals of the Technology Program are to (1) lower mission life-cycle costs; (2) develop innovative technologies; (3) develop and nurture an effective science-technology partnership; (4) stimulate cooperation among industry, academia, and government; and (5) identify and fund the development of important cross-Enterprise technologies.

SPACE SCIENCE RESEARCH PROGRAM

The goals of the Space Science Research and Analysis Program are: (1) to enhance the value of current space missions by carrying out supporting ground-based observations and laboratory experiments; (2) to conduct the basic research necessary to understand observed phenomena, and develop theories to explain observed phenomena and predict new ones; and, (3) to continue the analysis and evaluation of data from laboratories, airborne observatories, balloons, rocket experiments and spacecraft data archives. In addition to supporting basic and experimental astrophysics, space physics, and solar system exploration research for future flight missions, the program also develops and promotes scientific and technological expertise in the U.S. scientific community.

The goal of the Space Science Data Analysis program is to maximize the scientific return from our space missions, within available funding. The Data Analysis program is the source of the enormous scientific return generated from our investments in space hardware. Besides scientific advancements, the Data Analysis program also contributes to public education and understanding through media attention and our own education and outreach activities.

STRATEGY FOR ACHIEVING GOALS

TECHNOLOGY

The Space Science Enterprise's Technology Program consists of three major elements: core program, focused programs, and flight validation. These elements are designed to develop technologies from the conceptual stage to the point where they are ready to be incorporated in the full-scale development of science mission spacecraft.

Core Programs are comprised of two major components: Space Science Technology and Cross-Enterprise Technology.

Space Science Technology supports the development of enabling technologies for the next generation of high-performance Space Science missions. Retiring technological risk early in the mission design cycle, while emphasizing innovation to reach previously unattainable goals in mass reduction and performance, are key to the success of many of the missions planned for the next century. The Space Science Technology program includes Explorer Program Technology, Information Systems, High Performance Computing and Communications (HPCC), science instrument development, planetary flight support, and other OSS core technology. These elements are described below:

- Explorer Program Technology develops leading-edge technologies to enable partnerships in relatively small technology projects with industry, academia, NASA Field Centers, and other government agencies. These technologies must show application across multiple systems or missions, with an emphasis on meeting Explorer Program technology needs for improved spacecraft and instrument systems, and must also lead to lower mission costs.

- Information Systems provides technology for multidisciplinary science support in the areas of data management and archiving, networking, scientific computing, visualization, and applied information systems research and technology.

- The NASA HPCC Program will accelerate the development, application, and transfer of high-performance computing technologies to meet the science and engineering needs of the U.S. science community and the U.S. aeronautics community. Within this program the Space Science Enterprise funds the Remote Exploration and Experimentation (REE) component, which will develop low-power, fault-tolerant, high-performance, scaleable computing technology for a new generation of microspacecraft.

- Science instrument development funds initial technology work on new types of detectors and other scientific instruments. Many of these new instrument concepts are tested and flown aboard sounding rockets or balloons, and may later be adapted for flight aboard future free-flying spacecraft.

- The Planetary Flight Support (PFS) program provides ground system hardware, software, and mission support for all deep space missions. Planetary flight support activities are associated with the design and development of multi-mission ground operation systems for deep space and high-Earth-orbiting spacecraft. PFS also supports the development of generic multi-mission ground system upgrades such as the Advanced Multi-mission Operations System (AMMOS). This new capability is designed to significantly improve our ability to monitor spacecraft systems, resulting in reduced workforce levels and increased operations efficiencies for Cassini and future planetary missions. New missions in the Discovery and Mars Surveyor programs will work closely with the Planetary Flight Support Office to design ground systems developed at minimum cost, in reduced time, with greater capabilities, and able to operate at reduced overall mission operations costs.

- Other Space Science Core Technology provides funding to those technologies that are applicable to multiple focused programs (described below). Technologies eventually move from this category into a focused program if they are determined to be feasible and applicable to specific Space Science needs.

Two elements previously included in this category: Advanced Radioisotope Power System (ARPS) and the Center for Integrated Space Microsystems (CISM), have been moved to the Advanced Deep Space Systems focused program, since these technologies support the missions included under Advanced Deep Space Systems.

The Cross-Enterprise Technology program supports the cross-cutting technology requirements for all NASA Space Enterprises. The technologies are generally multi-mission in nature and this work tends to focus on the earlier stages of the technology life-cycle. The technologies developed under the Cross-Enterprise program form the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions.

A new feature of the Cross-Enterprise Technology program is the use of NASA Research Announcements (NRA) to broadly announce and compete an increasingly larger portion of the program. This will open up opportunities to a wider community of technology developers and will ensure the excellence of the program through peer-reviewed competition. The implementation of the NRA process in Cross-Enterprise Technology will begin in FY 99.

A second change implemented in FY 99 is the change in Cross-Enterprise Technology program structure. The new program structure is based on integrated, systems level "thrust areas", which are more clearly aligned with multi-Enterprise requirements and reflect the way the technology development work is managed. The thrust areas are as follows:

- Advanced Power and On-Board Propulsion: Subsystems and components that handle power generation, energy storage, and in-space propulsion to enable crewed and robotic spacecraft to travel faster and deeper into space, with longer mission duration.

- Sensors and Instrument Components: Breakthrough technologies for a wide range of remote sensing and observational capabilities for use in Space Science and Earth Science applications.

- Distributed Spacecraft: Precision formation-flying technologies, spacecraft constellations, and fleet control technologies.

- High Rate Data Delivery: Technologies to more efficiently collect, transmit, receive, store and access data from operational missions.

- Micro/Nano Spacecraft: Technologies to enable smaller, lower mass spacecraft with greater functionality. This area will also integrate developments from other thrust areas, such as miniature power, propulsion, instruments, and other components into functioning miniature spacecraft.

- Surface Systems: Technologies for spacecraft to operate and explore on the surface, below the surface, or in the atmospheres of planetary and other celestial bodies.

- Thinking Space Systems: Development of thinking, inquisitive, self-commanding systems that can recognize objects or phenomena of scientific interest and then conduct observations accordingly.

- Ultralight Structures and Space Observatories: Technologies enabling the deployment of large, lightweight space structures. These include precision deployment capabilities, membrane and inflatable structures, and high performance materials.

- Next Generation Infrastructure: Development of technologies to vastly improve the ability to conceive, design, test, and operate future space systems.

In FY 2000, additional funding for the Cross-Enterprise Technology program budget is provided to support three new initiatives: Self-sustaining Robotic Networks, Gossamer Spacecraft, and Next Decade Planning. Self-sustaining Robotic Networks ($24 million in FY 2000) will build on the success of Mars Pathfinder. This initiative's goal is to extend ongoing advances in spacecraft automation and minaturization to the critical set of technologies necessary to enable self-tasking, self-repairing, evolvable networks of small, highly mobile rovers for "virtual presence" planetary science and exploration in challenging environments. This funding will be placed in those thrust areas developing the relevant technologies, e.g., thinking space systems, surface systems, etc. Part of this funding is provided under the Administration's Information Technology (IT) initiative.

The Gossamer Spacecraft initiative will provide additional funding ($6 million in FY 2000) to the ultralight structures and space observatories thrust area to develop and demonstrate the deployment, control, and utility of thin-film deployable structures. Technologies developed in this area could support several future applications: solar sail propulsion, large aperture astronomical observatories, large aperture remote sensing, large-scale power collection and transmission in space, and interstellar precursor missions.

Next decade planning ($5 million in FY 00) will support improved cross-agency planning with the objective of improving technology selection through the ongoing development and refinement of a robust set of potential civil space programs that could be undertaken in the next decade.

Focused Programs are dedicated to high-priority technologies needed for specific science missions. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. Technology activities can encompass developments from basic research all the way to infusion into science missions. Focused Programs also includes mission studies -- the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions through detailed analysis of the trade-offs between design considerations and cost. In order to ensure that the decisions resulting from mission studies are realistic and can be implemented, the studies will employ new techniques for integrated design and rapid prototyping.

The FY 2000 budget estimate includes four categories of activities under focused programs. These categories correspond to the four scientific themes of the Space Science Enterprise: Astronomical Search for Origins, Advanced Deep Space Systems Development (Solar System Exploration), Sun-Earth Connections, and Structure and Evolution of the Universe. These elements are described below:

- Astronomical Search for Origins Technology develops critical technologies for studies of the early universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, vibration isolation and structural quieting systems, optical delay lines and large lightweight optics. Missions supported in this area include the Space Interferometry Mission (SIM), Next Generation Space Telescope (NGST), and Terrestrial Planet Finder (TPF), as well as the provision of interferometry capability to the ground-based Keck telescopes. This line also funds construction of the Optical Interferometry Development Laboratory at the Jet Propulsion Laboratory.

- Advanced Deep Space Systems Technology provides for the development, integration, and testing of revolutionary technologies for solar system exploration. Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. Funding for CISM and ARPS, previously budgeted in Core Technology, is now included in this line. Funding in this area supports a Europa orbiter mission with a launch date in 2003, and a potential Pluto/Kuiper Express mission in 2004.

Technology developed in this area also supports Solar Probe (a Sun-Earth Connections mission), which shares a significant amount of common technology with Europa and Pluto/Kuiper Express.

- Sun-Earth Connections Technology develops the technologies necessary for missions focused on observing the Sun and the effects of solar phenomena on the space environment and on the Earth. Technology funded in this area supports missions now under study such as STEREO, Solar-B, Solar Probe, as well as future SEC missions.

- Structure and Evolution of the Universe Technology provides for the development of technologies to study the large-scale structure of the universe, including the Milky Way and objects of extreme physical conditions. SEU missions are aimed at explaining the cycles of matter and energy in the evolving universe, examining the ultimate limits of gravity and energy in the universe and forecasting our cosmic destiny. Technology funded in this area supports missions now under study, such as FIRST and GLAST, as well as future SEU missions, particularly Constellation-X.

Flight Validation Program (also referred to as the New Millennium Program) provides a path to flight-validate key emerging technologies to enable exciting science missions. Breakthrough and enabling technologies are incorporated into spacecraft to provide a relevant flight testbed environment to validate the new technologies. Partnerships with industry, universities, and other government agencies are pursued, where feasible, to maximize both the return on investment in technology development and rapid infusion. Through the New Millennium Program (NMP), high-value technologies are made available for use in the Space Science program without imposing undue cost and risk on individual science missions. The New Millennium Program is funded by both the Space Science Enterprise and the Earth Science Enterprise.

In keeping with the focus of the New Millennium Program on providing flight validation of broadly applicable technologies, the NMP Deep Space-3 demonstrator, which will validate interferometry technologies to benefit future interferometry missions such as Terrestrial Planet Finder, has been moved to the Astronomical Search for Origins focused program. Similarly, the Deep Space-4 mission (Champollion/Comet Lander) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme. Moreover, the designation for these projects, along with all future New Millennium-type projects, has changed from Deep Space (DS) to Space Technology (ST), to reflect the fact that not all of the Space Science-funded demonstrators go to deep space. Thus, from this point on, DS-3 will be known as ST-3, and DS-4 as ST-4.

RESEARCH

The Space Science Research and Analysis Program carries out its goals and objectives by providing grants to universities, nonprofit and industrial research institutions, as well as by funding scientists at NASA Field Centers and other government agencies. Approximately 1,500 grants are awarded each year after a rigorous peer review process; only about one out of four proposals is accepted for funding. This scientific research is the foundation of the Space Science Enterprise. Key research activities include the analysis and interpretation of results from current and past missions; synthesis of these analyses with related airborne, suborbital, and ground-based observations; and the development of theory, which yields the scientific questions to motivate subsequent missions. The publication and dissemination of the results of new missions to scientists and the world is another key element of the Research and Analysis Program strategy, since it both inspires and enables cutting-edge research into the fundamental questions that form the core of the mission of the Space Science Enterprise.

The Space Science Data Analysis program supports scientific teams using data from our spacecraft. Depending on the mission, scientists supported may include Principal Investigators who have built hardware and been guaranteed participation, Guest Observers who have successfully competed for observing time, and researchers using archived data from current or past missions. Data analysis funding also supports a number of critical "Science Center" functions that are necessary to the operation of the spacecraft but do not involve the actual commanding of the spacecraft. For instance, the planning and scheduling of spacecraft observations, the distribution of data to investigators, and data archiving services are all supported under Data Analysis.

SCHEDULE & OUTPUTS

Technology Program

Space Science Core Technology

REE - FY 2000 Goals	The Remote Exploration and Experimentation (REE) element of the High Performance Computer and Communications (HPCC) program will demonstrate software-implemented fault tolerance for science applications. The target is to demonstrate applications on a first generation embedded computing testbed, with sustained performance degraded by no more than 25%, at fault rates characteristic of deep space and low Earth orbit.
First Generation computing testbed Plan: 2nd Qtr FY 1999	Install first generation scaleable embedded computing testbed operating at 30-200 MOPS/watt.
Demonstrate scaleable computer for spaceborne applications Plan: 3rd Qtr. FY 1999	Demonstrate scaleable spaceborne applications on first-generation embedded computing testbed.
Info System R&T - FY 2000	Information Systems R&T will demonstrate search, discovery, and fusion of multiple data

Goals	products at a major science meeting; accomplish and document the infusion of 5 information systems R&T efforts into flight projects for the broad research community; and space science data services shall be acknowledged as enabling for 2 interdisciplinary collaborations.

Cross-Enterprise Technology

Develop wide-band low-power electronically-tuned local oscillator sources up to 1.3 THz Plan: 3rd Qtr. FY 98 Revised: 4th Qtr. FY 99	This technology supports planned astronomy missions such as the Far Infrared Space Telescope (FIRST) mission to spectroscopically measure the chemical make-up of interstellar gases and nebulae. Plan has been revised to allow for incorporation of a new approach, using amplifiers which promise better performance (wider bandwith and lower power) to be incorporated into the local oscillator sources.
Develop a small advanced monopropellant rocket Plan: 4th Qtr. FY 98 Actual: 4th Qtr. FY 98	Fabricate and test flight-type nontoxic monopropellant system developed in FY 97. Completed on schedule.
Demonstrate 25% efficient Production-quality solar cells Plan: 4th Qtr. FY 98 Actual: 4th Qtr. FY 98	Pilot production of these efficient, new multi-band gap, large format solar cells will be done in FY 98. Completed on schedule.
NRA Release Plan: 2nd Qtr. FY 99	Release NASA Research Announcement (NRA) for Cross-Enterprise technology development.
Task selections Plan:4th Qtr. FY 99	Select tasks following competitive review of proposals submitted in the above NRA.
Conduct on-orbit Ranger telerobotic flight experiment Plan: 4th Qtr. FY 99 Current: Under review	This experiment will demonstrate multiple on-orbit robotic servicing capabilities relevant to science payload servicing and Space Station assembly and maintenance. The experiment has been temporarily removed from the manifest to accommodate other priorities. A late-FY 00 launch date is currently being evaluated.
Increase number of tasks at TRL 3 and below Plan: End of FY 2000	The number of tasks funded at technology readiness level (TRL) 3 (proof of concept) is a measure of the portion of the Cross-Enterprise program focused on early development, where a premium is placed on identification and "seed" support of leap-ahead technology developments. The goal is to increase TRL 3 tasks in FY 2000 by 100 vs. the FY 1999 level of slightly more than 200.
100% of tasks subjected to full	This goal will maintain the emphasis of maximizing competition in the cross-enterprise

and open competition and/or external non-advocate review Plan: End of FY 2000	technology program.

Focused Programs

Origins

ST 3 Project Start Plan: October 1997 Actual: February 1998	Begin Phase A.
KECK Interferometer Optics Telescope PDR Plan: August 1998 Actual: August 1998	Conduct Preliminary Design Review (PDR) for the build of 2-4 two-meter outrigger telescopes. Following contractor selection in June 1998, the PDR was completed on schedule.
ST 3 System Arch. Review Plan: August 1999	System Architecture & Requirements Review
Space Interferometry Mission (SIM) Plan: 2nd-4th Qtr. FY 1999	Continue Phase B activities and conduct the preliminary non-advocate review of the high precision astrometry and synthetic aperture imaging technologies for space-based interferometers. Key features include optical collectors on a 10-meter baseline and 10-milli-arcsecond synthesized imaging.
SIM Testbed Demo Plan: May 2000	The (SIM) System Testbed (STB) will demonstrate that RMS optical path difference can be controlled at 1.5 nanometers, operating in emulated on-orbit mode.
Keck fringe detection - FY 2000 Goal	Interferometric capabilities will be tested by detecting and tracking fringes with two test siderostats at 2 and 10 micron wavelengths
NGST – FY 2000 Goal	Complete the Next Generation Space Telescope (NGST) Developmental Cryogenic Active Telescope Testbed (DCATT) phase 1, measure ambient operation with off-the-shelf components, and make final preparations for phase 2, the measurement of cold telescope operation with selected "flight-like" component upgrades. These technologies are needed to mitigate risk in phasing and controlling segmented optics for the mission.

Deep Space

ST 4 Project Start	Begin Phase A.

Plan: October 1997 Actual: October 1997	
CISM Curriculum Plan: 4th Qtr. FY 1998 Current: 4th Qtr. FY 1999	Develop university curriculum for two CISM technology thrust efforts: Systems on a Chip, and Revolutionary Computing Technologies. Curriculum for Systems on a Chip completed July 1998. Curriculum for Revolutionary Comp. Tech. is expected to be completed 4th Qtr. FY 1999.
X-2000 Testbed design Plan: 4th Qtr FY 1999	First delivery of an integrated and tested spacecraft avionics testbed design.
Solar System Exploration (non-Mars) First mission C/D start FY 2000 Goal	Successfully complete a preliminary design for either the Europa Orbiter or Pluto-Kuiper Express mission, whichever is planned for earlier launch, that is shown to be capable of achieving the Category 1A science objectives with adequate cost, mass, power and other engineering margins.
ARPS Plan: March 2000	Fabricate and test 15 prototype AMTEC cells and Complete the final design of Alkali Metal Thermo-Electric Converter (AMTEC) cells
ARPS Plan: April 2000	Complete the final design for a 75-watt ARPS
X-2000 EM-1 Plan: April 2000	Deliver the first engineering model (EM-1) to the X-2000 project.
CISM Plan: 3rd Qtr FY 2000	Deliver first engineering model of an integrated avionics system.
Europa Orbiter Avionics Engineering Model I&T Plan: July 2000	Begin integration and test of the Avionics Engineering Model in 7/00.
ST 4 Critical Design Review Plan: September 2000	Complete the system CDR for DS4/Champollion, including successful completion of the avionics subsystem CDR and the mechanical subsystem CDR.
ARPS Plan: September 2000	Begin the prototype AMTEC 4-cell lifetime test and begin qualification unit fabrication

SEC

Complete phase B and transition to detailed design for Solar-B instruments Plan: 4th Qtr. FY 1999	Complete concept development for focal plane instrumentation for the optical telescope and X-ray telescope.
Complete STEREO Phase A Plan: June 2000	Complete STEREO Phase A studies by 6/00, including release of an AO for investigations with specific instruments and selection of the formulation phase payload.
Deliver Solar-B Electrical Engineering Models Plan: September 2000	Complete and deliver for testing Solar-B's four Electrical Engineering Models (EEMs).

SEU

Release RFP for GLAST Technology Development Plan: 2nd Qtr FY 1998 Actual: 2nd Qtr FY 1998	Release RFP for critical technology for tracker, anticoincidence shield, calorimeter, and data acquisition subsystems. Completed on schedule.
Release RFP for Constellation X-ray Technology Development Plan: 2nd Qtr. FY 1998 Actual: 2nd Qtr. FY 1998	Release RFP for critical technology development for hard X-ray telescope, Charge Coupled Device (CCD)/grating, and X-ray calorimeter. Completed on schedule.
FIRST Composite Mirror Plan: 4th Qtr. FY 1998 Actual: 4th Qtr. FY 1998	Demonstrate 2-meter class composite mirror with surface smoothness less than or equal to 2.4 microns RMS. Completed on schedule.
FIRST Technology Development Plan: 4th Qtr. FY 1999	Develop Key Technologies in the area of cryo coolers, mixers, bolometer arrays, and light weight 3.5 m telescope to prepare for C/D start in FY 2000 and launch in FY 2006.
STEREO: Complete Concept Definitions Plan: 4th Qtr. FY 1999	Complete preliminary concept definitions for spacecraft systems and instruments through peer reviewed NRAs.

FIRST instrument performance Plan: FY 2000	Demonstrate performance of the Superconductor-Insulator-Superconductor mixer to at least 8hv/k at 1120 GHz and 10hv/k at 1200 GHz. The U.S. contribution to the ESA Far Infared Space Telescope (FIRST) is the heterodyne instrument, which contains the SIS receiver.
GLAST prototype instrument performance – FY 2000	The prototype primary instrument for GLAST will demonstrate achievement of the established instrument performance level; angular resolution of 3.5 degrees across the entire 20 MeV to 100 GeV energy range.

Flight Validation (New Millennium Program)

<u>Deep Space 1</u>

DS 1 Ship to KSC Plan: April 1998 Actual: July 1998	Ship to KSC launch site. Delayed three months due to technical problems. Resulted in 3-month slip to launch.
DS 1 Launch Plan: July 1998 Actual: October 1998	First New Millennium technology demonstration flight. Launched in October 1998, three months late due to development problems. Spacecraft has now met minimum success criteria for 4 of 5 mission-defining technologies and 2 of 7 mission-enhancing technologies.

<u>Deep Space 2</u>

DS 2 Ship TMM for Environmental Test Plan: January 1998 Actual: January 1998	Ship thermal mass model for environmental testing with the Mars Surveyor 98 Lander Cruise Stage Spacecraft.
DS 2 Probe Ship to KSC Plan: October 1998 Actual: November 1998	Probe will be shipped to KSC for integration with Mars 98 Lander.
Launch DS 2 Plan: January 1999 Actual: January 1999	Piggyback on Mars 98 Lander.

Research Program

Space Science Research and Analysis

Issue NASA Research Announcement (NRA) Plan: February 1998 Actual: February 1998 Plan: February 1999 Actual: January 1999 Plan: February 2000	The OSS NRA for Research Opportunities in Space Science (ROSS) solicits proposals for basic SR&T investigations to seek to understand natural space phenomena and space related technologies across the full range of space science programs relevant to the four OSS science themes. Participation in this program is open to all categories of U.S. and non-U.S. organizations including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Minority and disadvantaged institutions are particularly encouraged to apply. Recommendations for funding are based on the evaluation of each proposal's science and technical merits, and its relevance to the OSS objectives as described in the NRA.

ACCOMPLISHMENTS AND PLANS

Core Technology Program

Space Science Core

The Explorer Technology initiative will identify, develop, infuse and transfer technologies that enable and enhance opportunities for frequent scientific investigations at the highest science value per unit cost. Procurement of the RAD6000 microprocessor chip in a multi-chip module format will enable a command and data handling "In Your Palm" Chip-on-Board technology demonstration to be incorporated in future SMEX missions. An Explorers NASA Research Announcement (NRA) was released in October 1998 and supports technology development in optical systems for instruments, data systems hardware and software, and guidance navigation and control. Grantees will be selected in spring 1999.

The Information Systems program will continue to provide reliable access for research communities and the public to obtain science data through the Planetary Data System, National Space Science Data Center, Space Telescope Science Institute, and High Energy Astrophysics Science Archive Research Center. Continuing advances in development and infusion of evolving information technology will increase the level of interoperability to support interdisciplinary research.

In High Performance Computing and Communication, the Remote Exploration and Experimentation project will continue to support the development of a first-generation testbed for scaleable spaceborne applications as well as embedded scaleable high-performance computers.

Science instrument development will continue to develop initial technologies for new sensors, detectors, and other instruments in support of specific space science research objectives. In many cases these technologies will be flown and validated as part of the suborbital program, either on balloons or rockets.

Planetary flight support will continue to develop the Advanced Multi-mission Operations System ground system upgrade, which will enable greater efficiency in the monitoring of spacecraft systems. This will allow us to continue to operate at a reduced level of overall mission operations costs.

Cross-Enterprise Technology

Activities within the Cross-Enterprise Technology program continue to focus on reducing spacecraft size, weight, and operating costs.

The Advanced Power and On-Board Propulsion Thrust Area developed the fundamental technology for the New Millennium Program's DS 1 ion propulsion system. The system started operation on November 24th, 1998. The Scarlett solar concentrator array, developed jointly with the Air Force Research Laboratory, was also successfully deployed on DS 1. Plans in this area include continued pursuit of performance improvements in multi-bandgap solar cells and NiMH and Lithium batteries. The use of titanium ion extraction grids is also being investigated as an alternate approach to provide a low-cost, low-risk, longer-life ion extraction system necessary for the next-generation of deep space science missions.

In the Sensors and Instrument Component Technology Thrust Area, accomplishments include a five-fold sensitivity improvement of low-cost, ultra-uniform, quantum infrared detectors for astronomical and infrared imaging applications. A demonstration utilizing a miniaturized precision micro-electronics/mechanical systems (MEMS) hygrometer flew in Atlantic Hurricane Bonnie on the NASA DC8, providing high-resolution, real-time humidity data to report and help predict the hurricane's movement and structure. Another demonstration featured a new low-cost (and size) MEMS micro-weather station as well as a sub-millimeter MEMS mixer. These new systems will now allow upper atmospheric sensing satellites to measure global chemical structure, composition and changes with higher fidelity to improve ozone prediction efforts. Work will continue on the development of lightweight structures and thin-film active arrays for high performance Synthetic Aperture Radar (SAR), which will dramatically reduce the projected fabrication cost and mass of these radar components.

A highlight in the Distributed Spacecraft thrust area was the completion of the integration and laboratory characterization of the Programmable Intelligent Micro-tracker (PIM) using an Active Pixel Sensor detector. The PIM represents a key component of the integrated high-performance guidance, navigation, and control (GN&C) capability required for precision formation flying and spacecraft constellation control. Other advances in development of GPS-based sensors for navigation and multi-spacecraft control algorithms will be built upon to validate an integrated operational capability.

High-Rate Data Delivery produced a software architecture for 4-kHz image acquisition from the Digital Integrated Camera Experiment (DICE) to be used for optical communications acquisition and tracking. Also, the hardware assembly of a 980 nano-meter boresight laser for the 1550 nano-meter Laser Transmitter Breadboard (LLBB) was completed, a key component for the development of an operational laser communications capability. Developments will continue for both near-Earth and deep space RF communications, including new traveling wave tube (TWT) and solid-state power amplifier components, phased-array antenna developments, and propagation models used by both the government and commercial communications sectors.

The Micro/Nano Spacecraft thrust area continued to focus developments on low-power and higher density electronics, and miniaturization of spacecraft subsystem components, such as MEMS propulsion. A holographic memory was successfully tested and demonstrated the potential for radiation-resistant on-board terabyte storage components in the next decade. Continued advancements in low-power, low-voltage VLSI circuits promise higher performance while significantly reducing both avionics and power component mass on spacecraft. Developments in adaptation of commercial processors for space use (including radiation hardening) will continue, emphasizing the use of proven designs to reduce development costs for the next generation of spacecraft for both near-Earth and deep space missions.

Investigators in the Surface Systems thrust area formulated, implemented, and validated Mars Sample Return rover capability including non-line-of-sight navigation, traversal of forty meters with a single command, approach and rock acquisition with a single command, and rock coring. They also conceived and validated capability for autonomous dust removal using charge polarity reversal and electroactive polymer wipers in support of nanorover exploration of asteroids. The Sprint "flying eye" was successfully demonstrated as an astronaut assistant. In addition, the design, fabrication, and testing of an anthropomorphic arm, wrist, and fingers in support of large platform maintenance (e.g. ISS) was completed.

The New Millennium Program DS 1 launched on October 24, 1998 carrying two experiments developed by the Thinking Space Systems thrust. They are the Beacon Monitor Operations Experiment (BMOX) and the Remote Agent Experiment (RAX). BMOX demonstrates the operational concept for reduced telemetry tracking baselined for Europa, Pluto and other missions, and validates Artificial Intelligent-based software for onboard engineering data summarization and beacon signaling. RAX demonstrates an architectural approach to onboard autonomy applicable to many future missions and validates onboard planning and scheduling, goal-oriented, robust execution, and automated mode identification and reconfiguration.

In the Ultra-Lightweight Space Structures and Observatories area, work progressed on the development of large inflatable and membrane deployable structures. A 16-meter x 7-meter model of the Next Generation Space Telescope (NGST) inflatable sunshield was developed and successfully deployed on the ground at the ILC Dover facility. Also, an inflatable solar array and inflatable Synthetic Aperture Radar (SAR) experiment was selected for year 2000 flight, from a Space Inflatables Program solicitation. In addition, 14-meter inflatable rigidizable struts for solar sail applications were fabricated and successfully tested.

In the Next Generation Infrastructure thrust, the Smart Assembly Modeler (SAM) is now in beta testing. SAM assembles FEM models from independently created part or component FEM models, which are platform independent, and allows component design engineers to predict and assess component performance when integrated into a real system.

In FY 2000 work will commence on three new items in the Cross-Enterprise Technology program: self-sustaining robotic networks, gossamer spacecraft, and next decade planning. Self-sustaining robotic networks will begin development of technologies necessary to extend ongoing advances in spacecraft automation and miniaturization to enable self-tasking, self-repairing, evolvable networks of small, highly mobile rovers for “virtual presence” planetary science and exploration in challenging environments. Gossamer spacecraft will begin developing ultralight structures and other technologies required to demonstrate the deployment, control, and utility of thin-film deployable structures. Next decade planning will support the development and refinement of concepts and technologies that are critical to developing a robust set of civil space initiatives during the FY 2001 to

FY 2010 timeframe. Examples of concepts that will be addressed by this initiative include human space flight beyond low-earth orbit, enabling a self-sustaining commercial space activity, and enabling the direct involvement of the public in space exploration.

Focused Programs

The Astronomical Search for Origins focused program will fund mission design and technology development for six elements in FY 1999 and 2000:

- An interferometry technology validation flight (New Millennium Space Technology-3; formerly included in the flight validation program) to demonstrate the concept of separated spacecraft interferometry. This 6-month flight demonstration, scheduled for launch in 2002, will utilize two spacecraft to validate precision formation flying and space interferometry. This activity has been transferred from the flight validation program to the Astronomical Search for Origins focused program since its purpose is to validate those technologies required for the Terrestrial Planet Finder mission (see below).

- Space Interferometer Mission (SIM) will be the world's first long-baseline operational optical space interferometer. It is scheduled for launch in FY 2005, assuming successful technology development. This mission has dual objectives: science and technology. The science objectives include astrometric detection of planets around other stars in our galaxy (mostly those of Uranus' mass but also some as small as several Earth masses), and precision location of very dim stars to an unprecedented accuracy: SIM will be a factor of 250 better in accuracy on stars 1000-times fainter than the best catalog currently available. The technology objective is to serve as the precursor to the future interferometry-based TPF mission. Specific technologies to be developed include precision laser metrology, controlled optics, optical delay lines, vibration isolation and structural quieting systems, and deployable structures.

- Next Generation Space Telescope (NGST) will combine large aperture and low temperature in an ideal infrared observing environment. NGST will allow astronomers to study the first protogalaxies, the first star clusters as they make their first generation of stars, and the first supernovae as they release heavy chemical elements into the interstellar gas. New technologies include precision-deployable structures, very large, low-area-density cold mirrors and active optics, and low-noise, large format infrared detectors. The target launch date is FY 2007.

- Keck Interferometer Phase 1enables NASA to capitalize on its significant previous investment in the Keck Observatory in Hawaii by connecting Keck's twin 10-meter telescopes into an 85-meter-baseline interferometer. At the time of Phase 1 completion in FY 2000, the Keck interferometer will become the world's most powerful ground optical instrument. Keck will be able to directly detect hot planets with Jupiter-size masses and will also be able to characterize clouds of dust and gases permeating other planetary systems. Phase 2 will add four 1.8-meter outrigger telescopes to the interferometer complement which will allow astrometric detection of Uranus-sized planets and will provide the capability to image protoplanetary discs. Phase 2 is planned to be completed in FY 2002

- Terrestrial Planet Finder (TPF) is aimed at the ultimate goal of the NASA's Origins program: to find Earth-like planets. Each of the precursor Origins activities, including the Space Infrared Telescope Facility (SIRTF), provides knowledge and technology needed for the design of the TPF. As currently envisioned, TPF will either be a large single-spacecraft interferometer or a group of several spacecraft (possibly copies of NGST) flown in precise formation. Thus, the experience and understanding gained in each step of the Origins program will be needed to make TPF successful.

- The Optical Interferometry Laboratory at the Jet Propulsion Lab will enable the development and verification of interferometry systems operating at the extremely high levels of precision required to meet the objectives of the Origins program. The new facility will include a high bay, a low bay, a ground support equipment room and three development laboratories. The budget includes Construction of Facilities funding of $2.5 million per year in FY 1999 and FY 2000 for this facility.

The Advanced Deep Space Systems focused program will continue to provide for the development, integration, and testing of revolutionary technologies for solar system and outer planetary exploration in FY 1999-2000. Technologies developed in this area will also support a Solar Probe mission (see below), which utilizes many of the same systems and technologies as Europa and Pluto/Kuiper. The primary focus of the Deep Space technology developments is to reduce the mass and volume of planetary spacecraft, toward the goal of a "spacecraft on a chip."

Key technology partnerships will be maintained with national laboratories and research agencies such as:

- Air Force Research Labs to develop radiation-hard microelectronics technology
- Sandia and Los Alamos National Laboratory to support MEMS, and ARPS technology;
- MIT Lincoln Labs to continue Advanced Semiconductor technology; and DARPA to continue ultra-scale computing and quantum computing technology.

Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. The Advanced Radioisotope Power Source (ARPS) activity will begin to develop a robust high-efficiency, low-mass, low-cost 100-watt-class electrical power source for deep space missions in FY 1998, and will develop advanced technologies for radioisotope power sources in the milliwatt and 10-watt class for future science missions. This activity, performed in partnership with NASA/JPL and the Department of Energy (DoE), will: increase the efficiency of thermal to electric converters; reduce the cost and time to fabricate, test and deliver flight ARPS for deep space missions; and provide breakthrough technology and/or multifunctional radioisotope power sources for future microspacecraft.

Since FY 1998, the Center for Integrated Space Microsystems (CISM) has been developing the advanced computing and avionics technologies that will enable miniaturized autonomous robotic spacecraft for deep-space exploration. These technologies will comprise the core of the advanced spacecraft development. A world-class facility for microelectronics system design, advanced simulation, rapid prototyping, and integration and test is being established at JPL in FY 1999. This facility will be electronically linked to industrial partners and collaborating universities as part of the distributed Collaborative Engineering Workbench technology.

Mission planning will support design and definition of the Europa Orbiter mission, targeted for launch in FY 2003, and the Pluto/Kuiper Express mission in FY 2004. Advanced Deep Space Systems also includes funding for the Champollion/Comet Lander mission, which has been transferred from the Flight Validation Program (where it was referred to as the New Millennium Program Deep Space-4 (Now Space Technology-4) mission), because it is a solar system exploration mission.

The focus for Sun-Earth Connections mission planning and technology activities will be directed toward the following future missions:

- Solar-B, a joint mission with the Japanese (ISAS spacecraft and launch), consists of a coordinated set of optical, EUV, and X-ray instruments that will apply a systems approach to the interaction between the Sun's magnetic field and its high temperature, ionized atmosphere. Technologies required by this mission include lightweight, stable optics and high-accuracy polarimetry for high-resolution (~0.1 arc sec) measurements of solar magnetic fields. Solar-B's expected launch date is FY 2004.

- STEREO is conceived as two smallsats in solar orbit. These spacecraft are to provide stereo imaging of solar corona, track solar mass ejections from the Sun to Earth using radio and optical instruments, and measure in-situ the solar wind and energetic particles (solar mass ejections appear to be a primary source of intense solar energetic particles events). STEREO's anticipated launch date is in FY 2004. However, OSS is reviewing options to accelerate this schedule, given Congressional interest.

- Solar Probe, the first close fly-by of a star (within 4 solar radii), requires a thermal shield to protect the payload from the Sun without releasing material that would contaminate the in-situ measurements. Because of its deep space flight trajectory, Solar Probe also requires many of the technologies being developed within the Advanced Deep Space Systems focused program, such as radiation hardening for the Jupiter swing-by and fly-by the Sun. The target launch date is FY 2007.

- Magnetospheric Multiscale is to be comprised of six spacecraft (four for in-situ measurements, two for global imaging) to study simultaneously the global behavior of the magnetosphere and the magnetospheric processes at the small scales where many of the basic interactions occur.

- Global Electrodynamics is a mission made up of five spacecraft, which will have an "atmospheric dipping" capability for investigating the electromagnetic coupling between the solar wind and upper atmosphere.

- Magnetospheric Constellation will support a fleet of 10-100 microsats using radio tomography and in-situ instrumentation to provide instantaneous global maps of plasma and field structures in the magnetosphere.

Structure and Evolution of the Universe mission planning and technology activities focus on development and demonstration of technologies necessary to implement the space missions outlined in the recent SEU Science and Technology Roadmaps. The priority missions include:

- Gamma Ray Large Area Space Telescope (GLAST). GLAST will study cosmic sources of high-energy particles and radiation (up to 300 GeV) with a large area, wide field-of-view, imaging telescope, using solid-state particle tracking technology. This technology is being developed in cooperation with DOE.

- ESA's Far Infrared and Submillimeter Space Telescope (FIRST). The U.S. participation on the FIRST mission substantially enhances the science goals with four key technologies: lightweight telescopes, cryocoolers, bolometer arrays, and heterodyne receivers.

- Constellation X-ray Mission. Constellation will use multiple satellites to enable a very large collecting area. Each spacecraft will be equipped with a high-throughput telescope for the low-energy band up to 10 keV, and three grazing-incidence telescopes for the high-energy band.

Flight Validation (New Millennium Program)

The DS-1 spacecraft successfully launched in 1998 and has partially validated four of the five mission-defining technology demonstrations. These technologies will complete their validation by the end of FY 1999. Validation of the remaining mission-defining technology, the miniature imaging camera spectrometer, awaits arrival at the relevant environment, an asteroid. The demonstration of the ion engine was especially important not only because it enables new destinations for science missions at lower cost than chemical propulsion, but also because it is planned for use in several U.S. commercial communications constellations in the near future.

The DS-2 mission also successfully launched piggyback on the Mars 98 Polar Lander in January 1999. This mission will arrive at Mars in December 1999, at which time the two DS-2 basketball-sized aeroshells will crash into the Martian surface at about 200 meters per second. Shattering on impact, each aeroshell will release a miniature two-piece science probe that will punch into the soil to a depth of up to two meters. The microprobes' primary science goal is to determine if water ice is present in the Martian subsurface- an important clue to the puzzle of whether life exists, or ever existed, on Mars. The tiny science stations will also measure soil temperature and monitor local Martian weather.

In keeping with the focus of the New Millennium Program (NMP) on providing flight validation of broadly applicable technologies, the NMP Space Technology-3 mission has been moved to the Astronomical Search for Origins focused program. ST-3 will validate technologies to benefit future interferometry missions such as Terrestrial Planet Finder. Similarly, the Space Technology-4 mission (Champollion/Comet Lander) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme.

Over the next several months, in addition to selecting the ST-5 mission, the Office of Space Science will undertake a thorough review of the New Millennium Program in order to assess the NMP's objectives, structure, management, and relationship to overall OSS goals. The intent is to ensure that the NMP is properly postured (in the ST-5 and post-ST-5 timeframe) to maintain its emphasis on technology validation, risk mitigation, and rapid infusion of technology into science missions.

Research

Research and Analysis

Our R&A program continued to produce exciting scientific results in FY 1998. NASA astronomers discovered what appears to be the clearest evidence yet of a budding solar system around a nearby star. An image from the Keck II telescope in Hawaii reveals the probable site of planet formation around the star HR 4796. The image shows a swirling disk of dust around the star, which is about 220 light-years from Earth in the constellation Centaurus. Within the disk is a telltale empty region that may have been swept clean when material was pulled into newly formed planetary bodies. It has been postulated that this may be what our solar system looked like at the end of its main planetary formation phase.

Research continues on the Martian Meteorite ALH84001 with most findings pointing to a non-life origin of many of the features. However, there are still several lines of mineralogical evidence that may point to life processes (e.g., origins of some of the iron oxides). Major new research tools that detect biomarkers (e.g., a new technique to use iron isotopes to indicate life activities) have been developed over the past year. These tools are being perfected and will be applied to the meteorite this year. In addition, a team of scientists has made their annual trek to the Antarctic to search for meteorites, particularly for other ancient Martian meteorites.

To coordinate our efforts to detect, track and characterize potentially hazardous asteroids and comets that could approach Earth, a new program office has been established at the Jet Propulsion Laboratory. The Near-Earth Object Program Office will focus on the goal of locating at least 90 percent of the estimated 2,000 asteroids and comets that approach the Earth and are larger than about 2/3-mile (about 1 kilometer) in diameter, by the end of the next decade. These are objects that are difficult to detect because of their relatively small size, but are large enough to cause global effects if one hit the Earth. In addition to managing the detection and cataloging of near-Earth objects, the new NASA office will be responsible for facilitating communications between the astronomical community and the public should any potentially hazardous objects be discovered as a result of the program. Science research solicitations and resulting peer reviews, international coordination, and strategic planning regarding future missions will remain the responsibilities of NASA Headquarters.

In recognition of the interrelationship between the origin and evolution of life and the origin and evolution of planets, a new program within the framework of Astrobiology was initiated in 1997. A multi-disciplinary Astrobiology Institute has been established with members from 11 geographically distributed research institutions, linked through advanced telecommunications. Examples of research accomplishments for the past year include the demonstration that the synthesis of protein-forming amino acids is more favorable in submarine hydrothermal systems than in surface seawater, suggesting a pre-biotic “nursery” for the origin of life on Earth. An analysis of the geologic record shows that the same evolutionary processes affecting the biotic transitions during “normal” times are not fundamentally different from processes operating during times of mass extinctions. And modeling of the heat pulses from large impactors hitting either early Mars or Earth suggests that life would have had an easier time surviving on Mars than Earth.

Data Analysis

NASA's Space Science spacecraft continue to generate a stream of scientific discoveries. Many of these findings are of broad interest to the general public, as witnessed by widespread media coverage. Recent highlights include results from Galileo, Hubble Space Telescope, Mars Global Surveyor, Lunar Prospector, and the Compton Gamma-Ray Observatory; however, many other Space Science spacecraft have been "in the news" and extremely scientifically productive as well. NASA is also finding ways to partner with the education community in order to strengthen science, technology, and mathematics education. Listed below are the top science stories of the past year from NASA Space Science missions, as selected by the Science Directors and Associate Administrator of Space Science at NASA Headquarters.

- HUBBLE GOES TO THE LIMIT IN SEARCH OF FARTHEST GALAXIES. The Hubble Space Telescope peered farther across space and further back into time than ever before, into a previously unseen realm of the universe. A "long exposure" infrared image taken with Hubble's Near Infrared Camera and Multi-Object Spectrometer (NICMOS) has uncovered the faintest galaxies ever seen, some of which could be over 12 billion light-years away, making them the farthest objects ever seen.

- POSSIBLE EXTRASOLAR PLANET DISCOVERED. The Hubble Space Telescope has given astronomers their first direct look at what may be a planet outside our solar system. Located 450 light-years away in the constellation Taurus, the object, called TMR-1C, is estimated to be 2-3 times the mass of Jupiter and appears to lie at the end of a strange filament of light. It is also possible that the object is a giant protoplanet or a brown dwarf star (a small star that has failed to sustain nuclear fusion).

- SHARPEST IMAGES OF MAGNETIC RECONNECTIONS ON SUN. Stunning detail in Images from the Transition Region and Coronal Explorer (TRACE) spacecraft reveal the first detailed observations of a magnetic energy release, called a magnetic reconnection. The magnetic reconnection was observed on May 8, 1998, in a region of the solar atmosphere where two sets of perpendicular magnetic loops expanded into each other. Magnetic reconnection occurs when magnetic fields "snap" to a new, lower energy configuration, much like when a twisted rubber band unwinds or breaks. A magnetic reconnection can release vast amounts of energy and is responsible for explosive events on the Sun, such as flares, that can cause communication and power system disruptions on Earth.

- MASSIVE BLACK HOLE FEEDING FRENZY. The Hubble Space Telescope provided an unprecedented look at the nearest example of galactic cannibalism -- a massive black hole hidden at the center of the nearby giant galaxy Centaurus A that is feeding on a smaller galaxy in a spectacular collision. The suspected black hole is so dense it contains the mass of perhaps a billion stars, compacted into a small region of space not much larger than our Solar System. Such fireworks were common in the early universe, as galaxies formed and evolved, but are rare today. Blue clusters of newborn stars and silhouettes of dust filaments are interspersed with blazing orange-glowing gas. Hubble's infrared vision has penetrated this wall of dust for the first time to see a twisted disk of hot gas swept up in the black hole's gravitational whirlpool.

- GALILEO PROVIDES MAJOR SCIENCE AT JUPITER. Jupiter's second largest moon, Callisto, may have a liquid ocean tucked under its icy, cratered crust, according to scientists studying data from the Galileo spacecraft. Key similarities were noted between Callisto and another of Jupiter's moons, Europa, which has already displayed strong evidence of a subsurface ocean. The main evidence is that Callisto's magnetic field is variable like Europa's, which can be explained by the presence of varying electrical currents, associated with Jupiter, flowing near Callisto's surface; these electrical currents flow in opposite directions at different times lending further credence to the presence of a subsurface ocean. Also, Galileo data show that Jupiter's intricate swirling ring system is formed by dust kicked up as interplanetary meteoroids smash into the giant planet's four small inner moons. Galileo images also reveal that the outermost ring is actually two rings, one embedded within the other.

- TREMENDOUS GAMMA-RAY FLARE BLASTS EARTH. An intense wave of gamma rays, emanating from a catastrophic magnetic flare on a mysterious star 20,000 light years away, struck the Earth's atmosphere on August 27, 1998, providing important clues about some of the most unusual stars in the Universe. The wave of radiation emanated from a newly discovered type of star called a magnetar-- a dense ball of super-heavy matter, no larger than a city but weighing more than the Sun with the greatest magnetic field known in the Universe. It powers a steady glow of X-rays from the star's surface, often punctuated by brief, intense gamma-ray flashes, and occasionally by cataclysmic flares like the one on August 27. This blast was detected by several of our spacecraft.

- NEW TYPE OF STAR DISCOVERED. A neutron star, located 40,000 light years from Earth, is generating the most intense magnetic field yet observed in the Universe, confirming the existence of a special class of neutron stars dubbed "magnetars." Magnetars have a magnetic field estimated to be one thousand trillion times the strength of Earth's magnetic field (a neutron star is a burned-out star roughly equal in mass to the Sun that has collapsed to about 10 miles across). This finding should help scientists calculate the rate at which stars die and create the heavier elements that later become planets and other stars. The magnetic field generated by this star is so intense that it heats the surface to 18 million degrees Fahrenheit. Data from the Compton Gamma-Ray Observatory, Rossi X-ray Timing Explorer, and Advanced Spacecraft for Cosmology Astrophysics led to this discovery.

- ICE ON MOON CONFIRMED. There is a high probability that water ice exists at both the north and south poles of the Moon, according to NASA's Lunar Prospector. The poles of the Moon may contain up to six billion metric tons of water ice, and evidence suggests that water ice deposits of relatively high concentration are trapped beneath the soil in the permanently shadowed craters of both lunar polar regions. In addition, Lunar Prospector found strong evidence that the Moon has a small, iron-rich core.

- BACKGROUND INFRARED GLOW TO UNIVERSE DISCOVERED. Astronomers using data from NASA's Cosmic Background Explorer (COBE), launched in 1989, made the first definitive detection of a background infrared glow across the sky produced by dust warmed by all the stars that have existed since the beginning of time. The telltale infrared radiation puts a limit on the total amount of energy released by all the stars in the universe. Astronomers say this will greatly improve development of models explaining how stars and galaxies were born and evolved after the Big Bang. The discovery reveals that a surprisingly large amount of starlight in the universe cannot be seen directly by today's optical telescopes, perhaps due to stars being hidden in dust, or being too faint or far away to be seen.

- LARGEST EXPLOSION SINCE BIG BANG. A recently detected cosmic gamma ray burst released a hundred times more energy than previously theorized, making it the most powerful explosion observed since the creation of the universe in the Big Bang. Scientists say that for about one or two seconds, this burst, which originated at about 12 billion light years from the Earth, was as luminous as all the rest of the entire universe. The burst appears to have released several hundred times more energy than a supernova, until now the most energetic known phenomenon in the universe. Finding such a large energy release over such a brief period of time is unprecedented in astronomy, except for the Big Bang itself.

- LATEST FROM MARS -- A warmer, wetter past. NASA's Mars Global Surveyor and Mars Pathfinder spacecraft suggest that the planet may have had thermal activity and was awash in water in its early history three billion to 4.5 billion years ago. Magnetized dust particles and the possible presence of conglomerates of smaller rocks, pebbles and soil suggest copious water in the distant past. In addition, the bulk of the Pathfinder landing site appears to have been deposited by large volumes of water, and the hills on the horizon known as Twin Peaks appear to be streamlined islands shaped by water. The first clear evidence of an ancient hydrothermal system implies that water was stable at or near the surface and that a thicker atmosphere existed in Mars' early history.

- SOLAR QUAKES. Scientists have observed for the first time that solar flares produce seismic waves in the Sun's interior that resemble those created by earthquakes. A moderate-sized flare on July 9, 1996, observed by the NASA/ESA Solar and Heliospheric Observatory (SOHO) spacecraft, generated a solar quake that contained about 40,000 times the energy released in the great 1906 earthquake that devastated San Francisco. The amount of energy released was enough to power the United States for 20 years at its current level of consumption, and was equivalent to an 11.3 magnitude earthquake.

- EXPANDING UNIVERSE. In Science magazine's top research advance of 1998, two international teams of astronomers provided a glimpse into the destiny of the universe when they looked at distant galaxies and found that they were rushing apart at an accelerating rate. Scientists discovered decades ago that the universe has been expanding since the Big Bang. But whether the gravitational pull between galaxies could slow - and ultimately reverse - that expansion has been unknown. This year's discovery showed that the expansion of the universe is in fact speeding up. This implies that gravity is no match for the force that is pushing the universe outward in all directions and that the expansion may continue, perhaps indefinitely. While the National Science Foundation funded much of the ground-based research behind these studies, data from NASA’s Hubble Space Telescope and from ROSAT also played a crucial role.

BASIS OF FY 2000 FUNDING REQUIREMENT

SUBORBITAL PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Balloon program	13,700	13,500	13,500
Sounding rockets	24,655	29,600	24,000
Total	38,355	43,100	37,500

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, 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. Activities are conducted on both a national and international cooperative basis.

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 or near both polar regions. The Balloon program is managed by the GSFC Wallops Flight Facility (WFF). Flight operations are conducted by the National Scientific Balloon Facility (NSBF), a government-owned, contractor-operated facility in Palestine, Texas.

Analytical tools have been developed to predict balloon performance and flight conditions. These tools are being employed to analyze new balloon materials in order to develop an ultra-long-duration flight capability (approximately 100 days), based on super-pressure balloons. An integrated management team has been established to develop and test the balloon vehicle and balloon-craft support system.

Sounding rockets are uniquely suited to perform low-altitude measurements (between balloon and spacecraft altitude) and to measure vertical variations of many atmospheric parameters. The sounding rocket program supports special areas of study, such as: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including aurora production of and energy coupling 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, Virginia; White Sands, New Mexico; and Poker Flat, Alaska, as well as occasional foreign locations. A performance-based contract was awarded in December 1998, in order to allow the government to transition away from operational control.

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's through master's degrees an opportunity to work on a reasonably complex project from its inception to its end, in a timeframe tenable within their academic careers. A NASA Research Announcement released in June 1996 offered 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. Six proposals were accepted during the proposal review in 1997. The selected experiments will be flown during 1998 and 1999. NASA expects to continue this program with release of a new research announcement in FY 1999.

The Spartan program provides reusable spacecraft, which can be flown aboard the Shuttle. These units can be adapted to support a variety of science payloads and are deployed from the Shuttle cargo bay to conduct experiments for a short time (i.e. several hours or days). Payloads are later retrieved, reinstalled into the cargo bay and returned to Earth. The science payload is returned to the mission scientists for data retrieval and possible refurbishment for a future flight opportunity. The Spartan carrier is also refurbished and modified as needed to accommodate the next science payload. A Spartan payload flew during the recent STS-95 (John Glenn) mission.

SCHEDULE & OUTPUTS

Balloon Program

FY 1998	28 flights were planned from Palestine, Texas, Fort Sumner, Canada, Alaska, and Brazil. 26 flights were attempted, and 25 missions flew successfully.
FY 1999	31 flights are planned.
FY 2000	Based on an overall goal of conducting 26 world-wide science and technology demonstration balloon missions, at least 23 campaigns shall successfully achieve altitude and distance and investigators' instrumentation shall function as planned for at least 19 missions.

Sounding Rockets

FY 1998	21 flights were launched from WFF, WSMR, and Puerto Rico. All flights and science missions were completely successful.
FY 1999	37 flights are planned, including 7 from Poker Flat, 7 from Norway, and 1 from Sweden.
FY 2000	Based on an overall goal of successfully launching 25 sounding rocket missions, at least 23 payloads shall successfully achieve their required altitude and orientation and at least 21 investigators shall achieve their minimum mission success goals

Spartan

FY 1998	Spartan 201-4 was deployed and retrieved on STS-87 in December 1997.
FY 1999	Spartan 201-5 was deployed and retrieved on STS-95 in November 1998.

ACCOMPLISHMENTS AND PLANS

In FY 1998, 25 balloons were flown for the core program of which 24 were successful flights. Of that number, 21 met their science success criteria. Capping years of technology development, the ultra-long duration ballooning (ULDB) capability has been repeatedly demonstrated and is now fully operational. Collaboration work with JPL was also initiated in order to identify technologies for ULDB that could be useful for planetary exploration programs such as Mars. The first demonstration of a 3mcf super-pressure balloon is planned for March 1999 with a full flight demonstration (extended global circumnavigation) in FY 2000.

The sounding rocket program achieved 100% flight and science success in FY 1998. Additionally, an active campaign in Puerto Rico occurred during this period. Work on the sounding rocket operations procurement resulted in announcement of an award in December 1998. FY 1999 will represent a very ambitious flight year, concurrent with transition to a new approach toward managing the program.

The Spartan 201-04 unsuccessfully deployed on STS-87 was reflown as 201-05 in November 1998. This mission was a complete success and demonstrated a new communication system for future Spartans. The mission also provided real-time solar imagery, which was transmitted over the internet. Work continues on advanced carriers, which could support Explorer missions, environmental science initiatives, as well as Space Station free-flyers.

BASIS OF FY 2000 FUNDING REQUIREMENT

LAUNCH SERVICES

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Launch services	27,600	--	--

The Launch Service budget has been distributed to the individual missions noted above. The FY 1998 funding reflects:

- Funding to complete payments for the launch of Cassini in October 1997 ($7.1 million). This funding is displayed here because there is no display for Cassini in this budget.

- Funding for multi-mission support such as engineering analysis and launch site operations and maintenance that was included in the Space Science FY 1998 Operating Plan and cannot be distributed to individual missions. After FY 1998, multi-mission support was moved to the Expendable Launch Vehicle Mission Support budegt line in the Payload Utilization and Operations section.