SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2002 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE **SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

	FY 2000 OPLAN REVISED	FY 2001 OPLAN REVISED	FY 2002 PRES BUDGET	Page Number
		(Thousands of Dollars)		
* Chandra X-ray Observatory	4,100			SAT 1-6
* Space Infrared Telescope Facility....................................	123,400	118,339	105,900	SAT 1-7
* Hubble Space Telescope (Development)	183,500	179,504	161,800	SAT 1-10
* Relativity (GP-B) Mission	49,900	41,209	40,200	SAT 1-12
* Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)	27,500	13,280	--	SAT 1-15
* Stratospheric Observatory For Infrared Astronomy	42,000	38,914	37,000	SAT 1-17
* Solar Terrestrial Relations Observatory (STEREO)	[8,300]	[21,900]	50,300	SAT 1-20
* Gamma-ray Large Area Space Telescope (GLAST)	[4,900]	[4,700]	19,400	SAT 1-22
Payload and Instrument Development...............................	14,450	33,426	44,800	SAT 1-24
* Explorers..	122,500	141,288	155,000	SAT 1-28
* Discovery	150,300	212,973	217,100	SAT 1-35
* Mars Exploration	248,800	427,564	430,900	SAT 1-39
Mission Operations	78,700	85,303	105,300	SAT 1-44
Technology Program...	581,200	419,245	478,800	SAT 1-50
Research Program..	567,450	596,773	606,500	SAT 1-70
Investments	[10,200]	13,171	--	SAT 1-76
[Construction of Facilities - included above]	[2,500]	[7,200]	[20,500]	
Institutional Support	[330,369]	[303,675]	333,362	SAT 1-77
Total..	2,193,800	2,320,989	2,786,362	

*Total Cost information is provided in the Special Issues section

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2002 ESTIMATES

BUDGET SUMMARY

Distribution of Program Amount by Installation	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Johnson Space Center	24,738	14,081	21,505
Kennedy Space Center	135,929	127,566	165,263
Marshall Space Flight Center	149,594	148,898	191,620
Ames Research Center	103,015	71,427	101,742
Langley Research Center	13,882	8,694	21,483
Glenn Research Center	28,633	2,670	7,639
Goddard Space Flight Center	803,618	857,896	1,164,043
Jet Propulsion Laboratory	826,855	957,761	978,719
Dryden Flight Research Center	75	75	188
Stennis Space Center	35	35	2,054
Headquarters	107,426	131,886	132,106
Total	2,193,800	2,320,989	2,786,362

PROGRAM GOALS

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

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

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

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

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

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

STRATEGY FOR ACHIEVING GOALS

Science

In the Space Science Enterprise we pursue the study of origins, as well as studies of the evolution and destiny of the cosmos, by establishing a continuum of exploration and science. We create a virtual presence in the solar system, exploring new territories and investigating the solar system in all its complexity. We simultaneously probe 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. We also send probes into interstellar space, beginning a virtual presence even beyond the solar system.

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

A key aspect of our strategic planning is to acquire the advice of the external science community, and in particular the National Academy of Sciences. The Enterprise also ensures science community input by utilizing peer review as broadly as possible. In addition, there is extensive collaboration with the science community, international partners, and other federal agencies, such as the National Science Foundation, Department of Defense, and Department of Energy, in the conduct of our missions, research and technology.

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

Education and public outreach

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

Our strategy begins with incorporating education and public outreach as an integral component of all of our activities — flight missions and research programs. It focuses on identifying and meeting the needs of educators and on emphasizing the unique contributions the Space Science Enterprise can make to education and to enhancing the public understanding of science and technology. During FY 2002, we will successfully achieve at least six of the following eight objectives:

(1) Ensure that every mission initiated in FY 2002 has a funded E/PO program, with a comprehensive E/PO plan prepared by its Critical Design Review (CDR).
(2) Ensure that by the end of FY 2002, ten percent of all research grants have an associated E/PO program underway.
(3) Plan and/or implement Enterprise-funded E/PO activities taking place in at least forty states.
(4) Ensure that at least ten Enterprise-funded research, mission development, mission operations, or education projects are underway in Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges, with at least three being underway in an institution of each type.
(5) Provide exhibits, materials, workshops, and personnel at a minimum of five national and three regional education and outreach conferences.
(6) Ensure that at least ten major Enterprise-sponsored exhibits or planetarium shows will be on display or on tour at major science museums or planetariums across the country.
(7) Prepare the second comprehensive Space Science Education/Outreach Report describing participants, audiences, and products for Enterprise E/PO programs.
(8) Initiate a major external review of the accomplishments of the Space Science E/PO efforts over the past five years, and complete development of the first phase of a comprehensive approach to assessing the E/PO program's long-term effectiveness and educational impact. When completed, the results of both studies will be used to guide further adjustments in program direction and content.

Technology development and transfer

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

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

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

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

BASIS OF FY 2002 FUNDING REQUIREMENT

CHANDRA X-RAY OBSERVATORY

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Chandra X-ray Observatory development *	4,100		

* Total cost information is provided in the Special Issues section

PROGRAM GOALS

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

STRATEGY FOR ACHIEVING GOALS

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

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

In December 1998 NASA announced that AXAF had been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. CXO was launched successfully by the Space Shuttle and an Inertial Upper Stage on July 23, 1999. Following launch, the spacecraft entered a period of checkout, followed by the start of science operations. The observatory is functioning superbly, and the science results have been spectacular, as reported below within the Data Analysis section of the Research budget. Current information is available on their web site at http://chandra.harvard.edu

BASIS OF FY 2002 FUNDING REQUIREMENT

SPACE INFRARED TELESCOPE FACILITY

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
SIRTF development *..	123,400	118,339	105,900

*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 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 over cosmic time of ultraluminous galaxies and quasar populations and probe their interior regions to study the character of their energy sources.

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

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

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

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

STRATEGY FOR ACHIEVING GOALS

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

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

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

Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team, is developing the Spacecraft Assembly. The spacecraft assembly consists of all of the elements of SIRTF that are needed for power, data collection, Observatory control and pointing, and communications. These elements of SIRTF are nominally operated at or near 300 degrees Kelvin, and 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 is being provided by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. This element will complete the assembly of the Observatory using the science instruments, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF are being performed by this element.

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

SCHEDULE & OUTPUTS

Instrument Development Plan: April 2000 Actual: December 2000	Deliver the Infrared Array Camera (IRAC), Multiband Imaging Photometer (MIPS), and Infrared Spectrograph (IRS) instruments. The instruments will perform at their specification levels at delivery. Delivery of IRAC was delayed until December 2000 due to hardware problems and completion of software development activities. The MIPS and IRS instruments were delivered on time.
Complete Spacecraft Plan: 2nd Qtr FY 2001 Revised: 3rd Qtr FY 2001	Complete the SIRTF Spacecraft and have it ready for integration with the Cryogenic Telescope Assembly (CTA).
Complete CTA Plan: 2nd Qtr FY 2001 Revised: 1st Qtr FY 2002	Complete the SIRTF Cryogenic Telescope Assembly (CTA), and deliver it to the spacecraft contractor for integration with the spacecraft. Revised due to delay in delivery of IRAC instrument (see above).
Integration & Test Plan: FY 2002	Complete integration and test of spacecraft and payload.

ACCOMPLISHMENTS AND PLANS

The flight model of the cryostat was completed on schedule in October 1999. As a result of the late delivery of the IRAC instrument, launch has been delayed from December 2001 until July 2002. All instruments have now been integrated into the cryostat and are working as designed. The Telescope Acceptance Review was completed in January 2001; the Telescope meets or exceeds all Level 1 requirements. A major flight software build was delivered and successfully tested in February 2001. As work continues in FY 2001-2002, the Spacecraft and CTA will be completed, consistent with the new launch schedule.

BASIS OF FY 2002 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Hubble Space Telescope Development...............................	183,500	179,504	161,800

PROGRAM GOALS

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

STRATEGY FOR ACHIEVING GOALS

HST was designed to be serviceable and requires on-orbit maintenance and replacement of spacecraft subsystems and scientific instruments about every three years. Ongoing modification and upkeep of system ground operations are also performed. Information regarding the launch of HST and the first three servicing missions (SM-1 in December 1993, SM-2 in February 1997, and SM-3A in December 1999) is available on-line at http://hubble.gsfc.nasa.gov/servicing-missions/ .

The fourth servicing mission, SM-3B, will install the new Advanced Camera for Surveys (ACS) instrument, which is chiefly designed for survey-mode photographs and discovery. It is estimated that ACS will increase Hubble's survey capability tenfold. SM-3B will also install a new set of solar arrays and a cooling system to extend the life of the NICMOS instrument, plus perform other repairs.

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

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

SCHEDULE & OUTPUTS

Observatory Upgrades/SM-3 Plan: May 2000 FY 2001 Budget: Actual/Revised: December 1999 and July 2001 FY 2002 Budget: Actual/Revised: December 1999 and May 2002	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B, now scheduled to occur no later than May 2002.
HST SM-3A Plan: October 1999 Actual: December 1999	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B by July 2001. SM-3A replaced all six gyroscopes, the spacecraft computer, and other hardware items.
HST SM-3B Plan: July 2001 Revised: May 2002	Install two key HST upgrades on Servicing Mission 3B: Advanced Camera for Surveys (ACS) and Solar Array 3 (SA3). HST hardware will be ready to support launch as early as November 2001; the actual launch date will depend upon Shuttle availability.
COS System Test Plan: FY 2002	Begin system test of the Cosmic Origins Spectrograph (COS).

ACCOMPLISHMENTS AND PLANS

HST continues to operate at the forefront of astronomical research. Some of HST's recent scientific results are described under the Data Analysis portion of the Supporting Research and Technology section of this document. All plans for Servicing Mission 3B are on track. Testing of the Advanced Camera for Surveys (ACS) science instrument, the replacement solar arrays, and other components is ongoing, in preparation for delivery to KSC as early as summer of 2001. The launch date will depend on availability of the Space Shuttle but will occur no earlier than November 2001.

Hardware development for SM-4 has also been progressing well. During FY 2002, the hardware will undergo a variety of tests, and plans for the sequence of tasks to be performed during the servicing mission will be refined.

BASIS OF FY 2002 FUNDING REQUIREMENT

RELATIVITY MISSION

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
GP-B Development *..	49,900	41,209	40,200

*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 test the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect". The dragging of space has never been measured, and the geodetic effect needs to be measured more precisely. Whether the experiment confirms or contradicts Einstein's theory, its results will be of the highest scientific importance. The measurements of both the frame dragging and geodetic effects will allow Einstein's Theory to be either rejected or given greater credence. The effect of invalidating Einstein's theory would be profound, and would call for major revisions of our concepts of physics and cosmology.

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

STRATEGY FOR ACHIEVING GOALS

This test of the general theory requires advanced applications in superconductivity, magnetic shielding, precision manufacturing, spacecraft control mechanisms, and cryogenics. The Relativity Mission spacecraft will employ super-precise quartz gyroscopes (small quartz spheres machined to an atomic level of smoothness) coated with a super-thin film of superconducting material (needed to be able to "read-out" changes in the direction of spin of the gyros). The gyros will be encased in an ultra-low magnetic-shielded, supercooled environment (requiring complex hardware consisting of lead-shielding, a dewar containing supercooled helium, and a sophisticated interface among the instrument's telescope, the shielded instrument probe, and the dewar). The system will maintain a level of instantaneous pointing accuracy of 20 milliarcseconds (requiring precise star-tracking, a "drag free" spacecraft control system, and micro-precision thrusters). The combination of these technologies will enable the Relativity Mission to measure: (1) the distortion caused by the movement of the Earth's gravitational field as the Earth rotates west to east; and, (2) the distortion caused by the movement of the Relativity Mission spacecraft through the Earth's gravitational field south to north, to a level of precision of 0.5 milliarcsecond per year (the width of a human hair observed from 16 miles).

The expertise to design, build and test the Relativity Mission, as well as the detailed understanding of the requirements for the Dewar and spacecraft, resides at Stanford University in Palo Alto, CA. 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). Lockheed Martin Missiles and Space is performing spacecraft development and systems integration.

SCHEDULE & OUTPUTS

Payload Flight Verification Plan: February 1999 Revised: July 2000 Revised: September 2001	Complete payload (dewar, science instrument, and probe) testing and verification. Schedule delay was driven by the need to repair the probe after failures during verification testing, by added system test content and by the need to repeat testing and verification.
Spacecraft Design, Fab, Assy, and Test Plan: March 1999 Revised: June 2000 Revised: August 2001	Complete the spacecraft design, fabrication, assembly, and test. Work has been deliberately slowed to allow more resources to be applied to the payload.
Flight Vehicle Integration and Test Plan: FY 2002	Initiate flight vehicle integration and test (I&T).
Final integration and test Plan: March 2000 Revised: September 2000 Revised: July 2001 Revised: August 2002	Complete final integration and test of the Gravity Probe-B science payload with the spacecraft.
Launch Plan: March 2000 Revised: October 2000 Revised: September 2001 Revised: October 2002	Successful launch and checkout. Launch has been delayed due to development problems cited above and to enable additional system testing.

ACCOMPLISHMENTS AND PLANS

Gravity Probe-B was proceeding toward a September 2001 launch date until a failure in the flight probe, discovered during payload flight verification, eliminated that possibility in the fall of 1999. De-integration of the payload and the implementation of design modifications were required, resulting in the program being re-baselined in March 2000 to a May 2002 launch. At the time of the rebaselining, the program was directed by the Agency Program Management Council to establish a set of critical milestones, which would be tracked by senior Agency management.

We are carefully and continuously monitoring all of the critical milestones, as well as the cost trends on this program. Should the program miss any of these milestones or should cost trends become unfavorable, NASA will initiate a termination review for Gravity Probe-B.

Accomplishments in FY 2000 included hardware rework. All eight of the FY 2000 critical milestones were completed on time.

The probe and Dewar were successfully re-integrated in October 2000. The decision to add additional test content (payload acoustic, sub-atmospheric refill trial and endgame gyro testing) resulted in the program being re-baselined again in November 2000 and Gravity Probe-B is now proceeding toward an October 2002 launch. The spacecraft is manifested to launch aboard a Delta II. In FY 2001, the program expects to complete the payload electronics and all integrated payload testing, with delivery of the payload to the spacecraft contractor by October 1, 2001.

BASIS OF FY 2002 FUNDING REQUIREMENT

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
TIMED Development *	27,500	13,280	

*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, for the first time, a core subset of measurements defining the basic states (density, pressure, temperature, winds) of the MLTI region and its thermal balance. 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 atmospheric variability so that the impact of these changes on tracking, spacecraft lifetimes, degradation of materials, and re-entry of piloted vehicles can be predicted. The mesosphere may also show evidence of anthropogenic effects that could herald global-scale environmental changes. TIMED will characterize this region to establish a baseline for future investigations of global change.

STRATEGY FOR ACHIEVING GOALS

The TIMED mission is the first science mission in the program of Solar Terrestrial Probes (STP). 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.

The program began its 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

Launch Plan: 1st Qtr FY 2001 Revised: 4th Qtr FY 2001	TIMED will be delivered on time for launch aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission, and will be completed within 10% of the planned development budget. TIMED was ready for launch in May 2000. However, due to Jason's inability to meet the May launch date, the launch is now scheduled for summer 2001. The planned development budget has been exceeded by more than 10% as a result of the Jason launch delay.

ACCOMPLISHMENTS AND PLANS

TIMED was ready for launch in May 2000 aboard a Delta II launch vehicle, co-manifested with Jason, an Earth Science mission. However, due to Jason's inability to meet the May launch date, the launch is now scheduled for summer 2001. TIMED will be delivered to support whatever launch readiness date is established for the Jason payload.

BASIS OF FY 2002 FUNDING REQUIREMENT

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Stratospheric Observatory for Infrared Astronomy	42,000	38,914	37,000

PROGRAM GOALS

The primary objective of the SOFIA program is to make fundamental scientific discoveries and contribute to our understanding of the universe through gathering and rigorous analysis and distribution of unique infrared astrophysical data. This objective 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 to meeting national goals for the reform of science, mathematics, and technology education, particularly at the K-12 level, and to 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 airborne systems have been able to provide to the science community very quick, global response to astronomical "targets of opportunity." 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 Kuiper Airborne Observatory (KAO) which it is replacing, SOFIA will facilitate significant advances in the study of a wide variety of astronomical objects. SOFIA is expected to operate for at least 20 years. 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.

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 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.

SCHEDULE & OUTPUTS

Telescope Assembly Critical Design Review Plan: November 1998 Revised: April 2000 Actual: April 2000	Formal review of the German contractor's concept for implementation of the telescope assembly. Slipped due to delays in the development of the German telescope assembly. Successfully completed in April 2000.
US System Critical Design Review Plan: September 1999 Revised: June 2000 Actual: June 2000	Formal review of the US concept for implementation of the observatory. Slipped due to delays in the development of the German telescope assembly . Successfully completed in June 2000.
Complete the 747 Section 46 Mockup Test Activity Plan: June 2000 Revised: 2nd Qtr FY 2001 Actual: 2nd Qtr FY 2001	Subject to replanning activities, it is anticipated that the U.S. systems CDR will be completed, the fuselage section mockup pathfinder work will be completed, and major aspects of the structural modification of the 747 SP will be underway. Successfully completed in 2nd Qtr. FY 2001.
Complete Forward Pressure Bulkhead Installation Plan: FY 2002	Complete installation of the forward pressure bulkhead.
Install Cavity Door on Fuselage Mockup Plan: 1st Qtr FY 2001 Revised: Under Review	Complete the installation of the flight cavity door on the 747 SP fuselage mockup, with no anomalies that would require redesign. Cost growth has forced a replanning of the SOFIA program schedule, which is ongoing as of March 2001. This activity will be delayed.
Complete 747 Structural Modification Plan: FY 2001 Revised: Under Review	Complete structural modification of the 747 SP. Cost growth has forced a replanning of the SOFIA program schedule, which is ongoing as of March 2001. This activity will be delayed.

ACCOMPLISHMENTS AND PLANS

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

Cost growth, first identified in late 2000, has forced a replanning of the SOFIA schedule, which is ongoing as of March 2001. The Ames Research Center is seeking to minimize the schedule impact and cost growth by all possible means.

BASIS OF FY 2002 FUNDING REQUIREMENT

SOLAR TERRESTRIAL RELATIONS OBSERVATORY (STEREO)

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Solar Terrestrial Relations Observatory (STEREO).............	[8,300]	[21,900]	50,300

PROGRAM GOALS

The primary objective of the STEREO mission is to understand the origin and consequences of coronal mass ejections (CMEs). CMEs are the most energetic eruptions on the Sun. They are responsible for essentially all of the largest solar energetic particle events and are the primary cause of major magnetic storms at Earth. STEREO will, for the first time, unveil the Sun in three dimensions. This will be achieved by sending two identically instrumented spacecraft, both in 1 Astronomical Unit orbits around the Sun, but one flying well ahead of the Earth and one behind. The instrument suite for STEREO will measure physical characteristics of CMEs with remote sensing and local sensing instruments, allowing scientists to determine solar origins of CMEs, their propagation into the interplanetary medium and ultimately their travel to Earth (for events directed toward Earth). By viewing CMEs in three dimensions, STEREO will be able to pinpoint their speed and distance from Earth, and thus more accurately time the arrival of the plasma cloud.

STRATEGY FOR ACHIEVING GOALS

The STEREO mission is the third mission in a planned program of Solar Terrestrial Probes (STP), as detailed in the Space Science Strategic Plan. STEREO's anticipated launch date is December 2004. The planned 2004 launch date will enable STEREO to make observations during the simpler, declining phase of the current activity cycle, which reached solar maximum in early 2001. The Johns Hopkins University Applied Physics Laboratory is responsible for developing the STEREO spacecraft, with instruments being provided by a number of U.S. and international science teams.

SCHEDULES & OUTPUTS

Development Contracts Plan: FY 2002	Have contracts in place for start of spacecraft and instrument detailed design and fabrication.

ACCOMPLISHMENTS AND PLANS

STEREO completed the System Requirements Review (SRR) and instrument selection in FY 2000. Phase A studies were completed in early FY 2001 and Phase B studies were started. THE STEREO confirmation review is planned for early FY 2002, marking the transition from formulation into implementation. After approval to proceed into implementation, STEREO will begin spacecraft and instrument detailed design and fabrication in FY 2002.

BASIS OF FY 2002 FUNDING REQUIREMENT

GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST)

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Gamma-Ray Large Area Space Telescope (GLAST)	[4,900]	[4,700]	19,400

PROGRAM GOALS

The primary objective of the GLAST mission is to understand the most powerful energy sources in the universe. The Universe in which we live is home to numerous exotic and beautiful phenomena, some of which can generate an almost inconceivable amount of energy. Because of their tremendous energy, gamma-rays travel through the Universe largely unobstructed. This means GLAST will be able to observe sources of gamma-rays near the edge of the visible Universe. GLAST will observe exotic objects like supermassive black holes, pulsars, and gamma-ray bursts, but will also probe the star formation history of the Universe and explore the physics of dark matter. Exploring these high-energy objects and events with the advanced technologies of GLAST could give us an entirely new understanding of our Universe and reveal unanticipated phenomena, particularly in fundamental physics.

STRATEGY FOR ACHIEVING GOALS

Because of their high energies, gamma-rays cannot be focused by a lens mirror like visible light in an optical telescope. The gamma-rays would pass, unaffected, directly through any such telescope. A gamma-ray telescope, therefore, makes use of detectors instead. GLAST will be equipped with two instruments for gamma-ray detection. These instruments, recently selected through peer-reviewed competition, are the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The LAT is the primary instrument for GLAST and is a next-generation gamma-ray telescope. The primary characteristics that distinguish the GLAST LAT from its predecessor are its wide field of view, greatly improved sensitivity (especially at the highest energies), superior positional accuracy, and timing accuracy free from electronic “dead-time” effects. The LAT’s detectors also do not depend on any expendable materials, so the instrument can have a long lifetime in orbit. The GBM is the secondary instrument aboard GLAST and is composed of two sets of detectors that will be used to aid in the study of gamma-ray bursts.

GLAST involves the cooperative efforts of the US Department of Energy as well as institutions in France, Germany, Japan, Italy and Sweden. Launch is planned for 2007 on a Delta-II rocket. A five-year mission life is assumed (goal of 10 years) with the first year dedicated to an all-sky survey followed by pointed observations.

SCHEDULES & OUTPUTS

GLAST Technology Development Plan: FY 2002	Conduct Large Area Telescope Preliminary Design Review (PDR).

ACCOMPLISHMENTS AND PLANS

GLAST will continue in formulation during FY 2001 with implementation planned for early FY 2002.

BASIS OF FY 2002 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Rosetta	6,950	7,284	1,300
Cluster-II	1,000	--	--
Solar-B	--	15,865	21,900
Spartan	500	499	500
Herschel	[16,100]	[15,500]	14,600
Other Shuttle/International payloads	6,000	9,778	6,500
Total	14,450	33,426	44,800

PROGRAM GOALS

Payload and Instrument Development supports the development of hardware to be used on international satellites or on Shuttle missions. International collaborative programs offer opportunities to leverage U.S. investments, and thus to obtain 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.

STRATEGY FOR ACHIEVING GOALS

The European Space Agency's Rosetta mission is a mission to a comet. The satellite will rendezvous with comet Wirtanen in late 2011, and orbit it while taking scientific measurements. During the cruise phase, the satellite will be given gravity assist maneuvers once by Mars (2005) and twice by the Earth (2005 and 2007). The satellite will also take measurements during fly-bys of two asteroids. U.S involvement in the Rosetta program includes the development of three remote sensing instruments, a subsystem for a fourth instrument, as well as support for an interdisciplinary scientist 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 its Ariane-5 launch vehicle. ESA and NASA approved reflight of the full mission (Cluster-II). The four spacecraft were successfully launched in the summer of 2000, and are carrying out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions.

Solar-B is an international cooperative mission between NASA, the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom, and the Institute of Space and Astronautical Science (ISAS) of Japan, which is leading the mission. Solar-B is the second mission in the Solar Terrestrial Probes (STP) Program and is a follow-on to the successful Solar A (or Yohkoh) mission. It will perform coordinated, simultaneous measurements of the different layers of the solar atmosphere from a Sun-synchronous orbit around the Earth. The data will be used to improve our understanding of the mechanisms that give rise to solar magnetic variability and how this variability modulates the total solar output and creates the driving force behind space weather. The U.S. Solar-B project provides optical, extreme ultraviolet, and x-ray instrument components to measure the Sun's magnetic field and UV/X-ray radiation. ISAS provides the spacecraft and launch vehicle and major elements of each of the scientific instruments. Solar-B's expected launch date is FY 2005.

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.

The Herschel Observatory (formerly called Far Infrared and Submillimetre Telescope or FIRST) is a cornerstone mission of ESA and will help to solve the mystery of how stars and galaxies were born. It will be launched on an Ariane-5 rocket together with Planck in 2007. NASA's contributions to Herschel include major components of two of the three instruments: the Spectral and Photometric Imaging Receiver (SPIRE) and the Heterodyne Instrument for FIRST (HIFI). Herschel has a minimum operational lifetime of three years and potentially offers about 7000 hours of science time per year.

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

The Shuttle/International Payloads program also funds U.S. development projects supporting Europe's International Gamma Ray Astrophysics Laboratory (INTEGRAL). 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.

SCHEDULE & OUTPUTS

Rosetta:

Qualification Model Deliveries Plan: May 2000 Actual: May 2000	Deliver the electrical qualification models for the four U.S.-provided instruments to ESA in May 2000 for integration with the Rosetta Orbiter. All electrical models/electrical qualification models were delivered in (or before) May 2000.
Flight Unit Deliveries Plan: 3rd Qtr FY 2001	Deliver the flight units for the four U.S.-provided instruments or instrument subsystems to ESA.

Cluster-II:

Instrument Analysis Software and Verification Plan: FY 2000 Actual: FY 2000	Complete the development of the Cluster-II instrument analysis software for the one U.S. and five U.S.-partnered instruments before launch and, if launch occurs in FY00, activate and verify the wideband data and U.S. subcomponents after launch. Software development was completed. The four spacecraft were launched in pairs on July 15, 2000 and August 9, 2000. All instruments have been activated on each of the spacecraft and their science data has been captured, analyzed, and verified.

Solar-B:

Pre-Environmental Review Plan: FY 2002	Conduct the Pre-Environmental Review for the U.S.-provided Extreme Ultraviolet Imaging Spectrometer (EIS).

Other Shuttle/International:

INTEGRAL Operations Readiness Plan: FY 2000 Actual: FY 2000	Prepare the INTEGRAL Science Data Center (ISDC) for data archiving and prepare instrument analysis software for the Spectrometer on INTEGRAL (SPI) instrument. Achieved through the use of two veteran software teams. The ISDC software has been completed, as have both portions of the SPI software, at a total cost 3.9% below the estimate.)
Planck Cooler Test Plan: April 2000 Revised: FY 2001	Assemble and successfully test the breadboard cooler for ESA's Planck mission. This milestone was not consistent with the phasing of program funding. Expect target to be completed in FY 2001.

Planck Cooler Performance Report Plan: 4th Qtr FY 2001	Deliver the Preliminary Breadboard Cooler Performance Report.
Planck HFI Flight Detectors Plan: FY 2002	Complete the High-Frequency Instrument (HFI) flight detectors.

ACCOMPLISHMENTS AND PLANS

All US-provided Rosetta engineering qualification and electronic models were delivered in FY 2000, and the US Rosetta flight instruments will be delivered to ESA by the 3rd quarter of FY 2001.

The four Cluster-II spacecraft were successfully launched in the summer of 2000, and are carrying out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions.

Solar-B completed PDR in May 2000. Shortly after PDR, ISAS announced a one-year slip in the launch date from August 2004 to September 2005. This resulted in Phase B being extended through December 2000 and a new schedule baseline. Solar-B received approval to proceed into implementation in December 2000 after the November Confirmation Review. Engineering models will be delivered in late FY 2001. Pre-environmental reviews will start in FY 2002.

Spartan continues as an advanced carrier, which could support Explorer missions, environmental science initiatives, as well as Space Station free-flyers.

INTEGRAL's pulse shape discriminator (PSD) and the instrument data analysis software simulator for the Integral Spectrometer (SPI) were successfully delivered to CNES during FY 2000. The spectroscopic data analysis software for science data analysis was also delivered to the Integral Science Data Center (ISDC). Monte Carlo simulations of the background and source response of the SPI for science data analysis will be performed during FY 2001, as will software checkout.

Herschel's Confirmation Review is planned for the third quarter of FY 2001 and instrument fabrication will begin in FY 2002.

During FY 2000, PLANCK completed the formulation and preliminary design phase, resulting in a successful project Preliminary Design Review and Confirmation Readiness Review. In FY 2001 PLANCK will complete its Confirmation Review and begin implementation and detailed design.

BASIS OF FY 2002 FUNDING REQUIREMENT

EXPLORER PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Imager for Magnetopause-to-Aurora Global Exploration.................	6,400	--	--
Microwave Anisotropy Probe..	28,000	18,492	--
Swift Gamma Ray Burst...	22,200	49,050	47,400
Full-sky Astrometric Mapping..	5,200	19,954	61,700
Small Explorer (SMEX) Program	48,800	37,023	8,400
Explorer Planning (All Others)...	11,900	16,769	37,500
*Total	122,500	141,288	155,000

*Total cost information is provided in the Special Issues section.

PROGRAM GOALS

The goal of the Explorer Program is to accomplish frequent, high-quality space science investigations utilizing innovative, streamlined, and efficient management approaches. The program seeks to substantially reduce mission cost through commitment to, and control of, design, development, and operations costs, as well as to reduce cost and improve performance through the use of new technology. Finally, Explorers seek to enhance public awareness of, and appreciation for, space science and to incorporate educational and public outreach activities as integral parts of space science investigations. Investigations selected for Explorer projects are usually of a survey nature, or have specific objectives not requiring the capabilities of a major observatory.

STRATEGY FOR ACHIEVING GOALS

Explorer mission development is managed within an essentially level funding profile. New mission starts 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, the Medium-class (MIDEX) missions launched by Delta Expendable Launch Vehicles (ELVs), and moving down through the Small-class (SMEX) missions launched on Pegasus-class ELVs and the University-class (UNEX) missions generally co-manifested with larger payloads on a variety of launchers. Funding for launch services and mission studies is included within the Explorer budget. The Explorer Program Office at the Goddard Space Flight Center (GSFC) manages mission definition, development, and launch of these missions. For further information on the Explorer missions, visit the website at http://explorers.gsfc.nasa.gov/index.html.

Medium Class

The Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in all OSS themes. The MIDEX investigations are characterized by definition, development, launch service, and mission operations and data analysis cost not to exceed $170 million (in Fiscal Year 2002 dollars) total cost to NASA. NASA's goal is to launch one MIDEX mission per year.

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

In October 1999, NASA selected MIDEX 3 & 4, the Swift Gamma Ray Burst Explorer (Swift) and Full-sky Astrometric Mapping Explorer (FAME) missions. Swift is a three-telescope space observatory for studying gamma ray bursts. Dr. Neil Gehrels of NASA's Goddard Space Flight Center will lead the Swift mission. FAME is a space telescope designed to obtain highly precise position and brightness measurements of 40 million stars. Dr. Kenneth J. Johnston of the U.S. Naval Observatory will lead the FAME mission.

An Announcement of Opportunity for MIDEX 5 & 6 is planned for release in the summer of 2001. A Step-1 selection is planned for early CY 2002, followed by a Step-2 selection in the fall of 2002.

Small Class

The Small Explorer (SMEX) program provides frequent flight opportunities for highly focused and relatively inexpensive missions. SMEX investigations are characterized by a total cost to NASA for definition, development, launch service, and mission operations and data analysis not to exceed $85 million (in Fiscal Year 2002 dollars). It is NASA's goal to launch one Small Explorer mission per year.

The High Energy Solar Spectroscopic Imager (HESSI) and the Galaxy Evolution Explorer (GALEX) missions were selected in October 1997. HESSI will observe the Sun to study particle acceleration and energy release in solar flares. The Galaxy Evolution Explorer (GALEX) is an Ultraviolet Small Explorer mission that will map the global history of the universe through 80 percent of its life. GALEX will probe the causes of star formation during that period in which galaxies evolved dramatically, and most stars, elements, and galaxy disks had their origins. HESSI is being developed by the University of California at Berkeley. The GALEX mission is being developed by the California Institute of Technology.

An Announcement of Opportunity for the next two SMEX missions was released in December 1999. Seven SMEX proposals and one Mission of Opportunity proposal were selected in September 2000 for concept studies, and one Mission of Opportunity proposal was selected for flight. The eight missions selected for study will begin a six-month concept study not later than October 2001. After a thorough evaluation of the results of Phase A studies has been completed, NASA expects to select two SMEX missions for launch in 2004 and 2005. NASA may or may not select the Mission of Opportunity for flight.

Student Explorer Demonstration Initiative and University Class

The University-class Explorer (UNEX) program was initiated to enable a higher flight rate to provide the academic community with routine access to space science research. The UNEX program supports very small, low-cost missions managed, designed and developed at universities, in cooperation with industry. The program has sought to develop greater technical expertise within the academic community beyond the suborbital class missions currently being flown aboard balloons and sounding rockets, thus creating greater opportunity for students and reducing the required role of NASA in-house expertise.

From responses to a UNEX AO released in January 1998, NASA selected Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) and IMEX. CHIPS will use an extreme ultraviolet spectrograph during its one-year mission to study the "Local Bubble," a tenuous cloud of hot gas surrounding our solar system that extends about 300 light-years from the Sun. CHIPS will be developed by the University of California Berkeley. SpaceDev will build the CHIPS spacecraft. IMEX was to have entered Phase B in FY 2001. However, in January 2001the project was not confirmed for preliminary design due to cost growth.

The UNEX precursor missions under the Student Explorer Demonstration Initiative (STEDI) included the Cooperative Astrophysics and Technology Satellite (CATSAT). CATSAT is being developed by the University of New Hampshire with launch planned in 2002.

MISSIONS OF OPPORTUNITY

Missions of Opportunity (MO) were instituted within the Explorer Program as part of the previously mentioned SMEX AO. MO are space science investigations, costing no more than $35 million in FY 2002 dollars, that are flown as part of a non-NASA space mission. MO is conducted on a no-exchange-of-funds basis with the organization sponsoring the mission. OSS intends to solicit proposals for MO with all future Explorer AOs.

HETE-II, an international (France, Italy and Japan) collaboration, was launched in October 2000 from Kwajalein Island. HETE-II will obtain precise positions of gamma-ray bursters and other high-energy transient sources. HETE-II is a replacement for HETE-I, which was lost in November 1996 due to launch vehicle third-stage power failures.

Under the 1997 SMEX AO, the Two Wide-Angle Neutral-Atom Spectrometers (TWINS) investigation was selected as a MO. TWINS will enable three-dimensional global visualization of Earth's magnetospheric region, thereby greatly enhancing understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. Los Alamos National Laboratory (LANL) is developing instruments for the TWINS mission.

Under the 1999 SMEX AO, the Coupled Ion-Neutral Dynamics Investigations (CINDI) were selected as a MO. CINDI will provide two instruments for the Air Force's Communications/Navigation Outage Forecast System (C/NOFS) satellite that will lead to a better understanding of the dynamics of the Earth's ionosphere.

SCHEDULE & OUTPUTS

Medium-class Explorer Program

IMAGE	
Delivery, Launch	IMAGE will be delivered for an on-time launch.
Plan: February 2000	
Actual:	IMAGE launched successfully on March 25, 2000. IMAGE was delivered early (in September).
Delivered September 1999 Launched March 2000	Note: Red Team review and industry-wide electronic part (Interpoint converter) alert caused a six-week launch delay.
MAP	
Begin Environmental Testing	Begin system-level environmental testing of the spacecraft.
Plan: July 2000	
Actual: September 2000	Testing began in September 2000, a slight delay due to technical problems with electronic parts (Interpoint converters). Industry-wide alert led to change-out.
Delivery, Launch	Deliver MAP for launch.
Plan: 1st Qtr FY 2001 Revised: 3rd Qtr FY 2001	Delayed primarily due to difficulties in completing thermal blanketing during spacecraft integration.
Swift	
Spacecraft Subsystems	Complete build-up of spacecraft subsystems.
Plan: FY 2002	
FAME	
Confirmation Review	Conduct Confirmation Review (CR).
Plan: FY 2002	

Small-class Explorer Program

<u>HESSI</u>	
Delivery, Launch Plan: July 2000 Actual/Revised: Delivery: January 2001 Launch: 3rd Qtr FY 2001	HESSI will be delivered in time for a planned July 2000 launch. Spacecraft damaged during system vibration test. Shipment for launch occurred in January 2001.
<u>GALEX</u>	
Instrument Delivery Plan: July 2000 Revised: 4th Qtr. FY 2001	Deliver the GALEX science instrument from JPL to the Space Astrophysics Laboratory at Caltech during April 2000 for science calibration. The instrument will be fully integrated, functionally tested, and environmentally qualified at the time of the delivery. Problems in detector development and telescope fabrication, coupled with delays in electronics development due to loss of key manpower resulted in the slip of this milestone. Will ship in late FY01.
Delivery, Launch Plan: 4th Qtr., FY 2001 Revised: FY 2002	Deliver GALEX for launch. Slipped due to the instrument problems cited above.
<u>TWINS</u>	
Component Deliveries Plan: March 2000 Revised: 3rd Qtr., FY 2001	Deliver to the Los Alamos National Laboratory, in March 2000, all components for system integration and testing of the first flight system for the TWINS mission. The TWINS mission is a payload of opportunity. All components were ready for acceptance as required. However, as requested, delivery has been delayed to accommodate the schedule of the non-NASA host spacecraft. Accordingly, delivery of the first flight model components, including the electronics box, is scheduled to occur by mid-FY01.
Complete Flight Model #1 Plan: FY 2002	Complete work on flight model #1 to be ready for delivery.

University-class Explorer Program

CATSAT

Launch	Deliver the CATSAT for launch.
Plan: 4th Qtr FY 2001	
Revised: FY 2002	Delayed due to uncertain launch accommodations and issues with launch partner, ICESAT.

HETE-II

Launch	Complete HETE-II development and launch spacecraft.
Plan: December 1999 Revised: January 2000 Actual: October 2000	HETE –II was launched on October 9, 2000. Launch delay was due to: delays in gaining the approval required for launches from Kwajalein Island; the addition of Red Team Review; and the temporary grounding of all NASA Pegasus ELVs, which has since been lifted.

AO Activities

SMEX AO Selection	Mission selection, leading to concept studies.
Plan: 1st Qtr FY 2000	
Revised: 4th Qtr. FY 2000	Seven SMEX missions were selected for concept studies.
Actual: 4th Qtr. FY 2000	
SMEX Selection	Down-selection (Step 2) for SMEX 8 and SMEX 9.
Plan: FY 2001	
Revised: FY 2002	Due to budget constraints, the down-selection of two missions for flight has been delayed until FY 2002.

ACCOMPLISHMENTS AND PLANS

The Explorers Program launched one mission during FY 2000: IMAGE successfully launched from Vandenberg AFB on March 25, 2000. Spacecraft and instrument development for the MAP, HESSI and GALEX missions continued throughout FY 2000, although HESSI suffered a setback in March when it sustained substantial damage during vibration testing. The spacecraft's structure was damaged and two of the four solar arrays were cracked. TWINS held a successful critical design review in February 2000 and development is proceeding with no problem. Formulation for Swift, FAME and CHIPS continued. However, the decision not to proceed with IMEX beyond the extended Phase A study was made in January 2001 due to growth in cost estimates. In September 2000, seven SMEX proposals and one Mission of Opportunity proposal were selected for concept studies and one Mission of Opportunity proposal was selected for flight.

Three missions are targeted for launch in fiscal year 2001: HETE-II, which was launched in October 2000; HESSI in spring 2001; and MAP in summer 2001. Both CHIPS and SWIFT completed formulation and were confirmed for implementation in December 2000 and February 2001, respectively. Delivery of the TWINS first flight model, including electronics box, to the Los Alamos National Laboratory is scheduled to occur by mid-FY 2001. The GALEX science instrument will be shipped in late FY 2001 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. CINDI will begin its concept study in FY 2001, which, after review, will be followed by definition, a confirmation review and implementation.

During preparation of the FY 2002 budget, NASA determined that the Space Science UNEX program was not producing sufficient scientific return on the Agency's investment. The student training opportunities on UNEX missions have also been deemed to be too limited. As a result, NASA is deferring selection of any new UNEX missions indefinitely.

Three Explorer missions are planned to launch in FY 2002: GALEX, CATSAT, and CHIPS. Swift plans to complete build-up of the spacecraft subsystems in FY 2002 and FAME will go through its Confirmation Review. TWINS expects to complete work on flight model #1 and CINDI will continue formulation. It is expected that two SMEX missions will be down-selected for flight, and potentially a Mission of Opportunity, during FY 2002.

BASIS OF FY 2002 FUNDING REQUIREMENT

DISCOVERY PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Genesis *	62,300	25,486	--
CONTOUR *	52,100	53,881	26,500
MESSENGER	--	31,730	97,400
Deep Impact	--	57,174	84,200
Future Missions	35,900	44,702	9,000
Total	150,300	212,973	217,100

*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. Missions are selected through open, peer-reviewed competitions, to ensure science community involvement while enhancing the U.S. return on its investment. The Discovery program also aids in the national goal to transfer technology to the private sector. The cost of building, launching, and operating a Discovery mission must not exceed $300 million in FY 2001 dollars, and the mission must launch within three years from start of development.

STRATEGY FOR ACHIEVING GOALS

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. Genesis will return samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud. The mission is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA. JPL will provide the payload and project management, while Lockheed Martin Astronautics of Denver, CO will provide the spacecraft.

The Comet Nucleus Tour (CONTOUR) mission is intended 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 Johns Hopkins University Applied Physics Laboratory (JHU/APL) of Laurel, MD provides the spacecraft and project management.

In July 1999, two new Discovery missions were selected, Deep Impact and MESSENGER, and in October 1999, the first Discovery Mission of Opportunity, ASPERA-3, was approved for implementation. Deep Impact is designed to fire a large (up to 500 kilogram) copper projectile into the comet P/Tempel 1, excavating a large crater more than 65 feet (20 meters) deep, in order to expose its pristine interior ice and rock. The impactor will be separated from the flyby spacecraft 24 hours prior to its impact on the surface of the comet. The impactor will have an active guidance system to steer it to impact on the sunlit side of the comet surface. The impactor will also relay close-up images of the comet's surface prior to impact back to the flyby spacecraft for downlink to Earth. Optical and infrared instruments on the flyby spacecraft will image and spectrally map the impact and resulting crater. The Deep Impact mission is led by Principal Investigator, Dr. Michael A'Hearn from the University of Maryland. Ball Aerospace & Technologies Corp. and JPL will develop the flight hardware and ground systems.

The Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) mission will send an orbiter spacecraft carrying seven instruments to globally image and study the closest planet to the Sun. MESSENGER will be implemented by a consortium headed by the Principal Investigator, Dr. Sean Solomon of the Carnegie Institution of Washington. MESSENGER will be designed and built by JHU/APL, in collaboration with industrial partners GenCorp Aerojet (propulsion system) and Composite Optics, Inc. (integrated structure). JHU/APL, NASA/Goddard Space Flight Center, the University of Colorado, and the University of Michigan are supplying instruments and instrument subsystems. The Science Team is comprised of Co-Investigators from various institutions.

The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) is a Discovery Mission of Opportunity that will provide parts of a scientific instrument to study the interaction between the solar wind and the atmosphere of Mars. It will fly aboard the European Space Agency's Mars Express spacecraft. The U.S. principal investigator being funded by NASA is Dr. David Winningham of the Southwest Research Institute, San Antonio, TX.

SCHEDULE & OUTPUTS

Genesis

Start Functional Testing Plan: November 1999 Actual: February 2000	Complete Genesis spacecraft assembly and start functional testing. Functional testing started on schedule in November 1999. However, a few spacecraft subsystems were delivered after this date, delaying completion of assembly. The work was fully completed as of February 2000. The slip was absorbed out of schedule reserves, with no impact to launch date.
Launch Plan: 2nd Qtr FY 2001 Revised: 3rd Qtr FY 2001	Deliver for launch. Genesis was initially scheduled to launch in January, 2001, but due to the need for JPL to concentrate their resources on the Mars Odyssey mission, and due to a conflict with the desired launch of the MAP Explorer mission, Genesis launch has been rescheduled for late July 2001.

CONTOUR

Preliminary Design Review	Complete a PDR that confirms the design and maintains 15% margins for mass and power.
Plan: 2nd Qtr FY 2000	
Actual: 2nd Qtr FY 2000	PDR was successfully completed; margins were at or above 15%.
Complete Imager Breadboard	Successfully complete the breadboard of the imager instrument for CONTOUR.
Plan: September 2000	
Actual: September 2000	Imager instrument breadboard successfully completed.
Propulsion System Contract Award	Award the contract for the propulsion system following successful PDR.
Plan: FY 2000	PDR was successful; propulsion system contract was awarded.
Actual: FY 2000	
Critical Design Review	Successful CDR, meeting all program level requirements.
Plan: FY 2001	
Actual: December 2000	CDR was successfully completed in December 2000.
Environmental Testing	Complete environmental testing.
Plan: FY 2002	

MESSENGER

Critical Design Review	Conduct Critical Design Review (CDR).
Plan: FY 2002	

Announcements of Opportunity (AOs)

AO Release	Release an AO for the next Discovery mission.
Plan: FY 2000	
Actual: FY 2000	The AO was released on May 19, 2000.
Mission Selection	We expect the next down-select to take place in late summer 2001.
Plan: FY 2001	

ACCOMPLISHMENTS AND PLANS

During FY 1999, Genesis detailed design activities were completed, leading to the Critical Design Review in July 1999. System level integration and test activities will occur during FY 2000, with delivery to KSC in time for launch in July 2001.

The CONTOUR Preliminary Design Review and Confirmation Review were completed in January 2000. Development started in February 2000, leading to a Critical Design Review completed in December 2000.

MESSENGER and Deep Impact continued in the formulation phase through FY 2000, leading to planned Preliminary Design Reviews in FY 2001; in March for Deep Impact and August for MESSENGER, followed by confirmation reviews and the potential start of implementation.

A Discovery AO was released in May 2000 and three new missions, plus a contribution to a French-led Mars mission, were selected in January 2001 for further definition. Final selection(s) are expected in late FY 2001.

BASIS OF FY 2002 FUNDING REQUIREMENT

MARS EXPLORATION PROGRAM

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
2001 Mars Odyssey*	109,200	38,316	--
2003 Mars Exploration Rovers (MER) *	18,900	302,000	207,000
Future Missions	120,700	87,248	223,900
[Construction of Facilities]	[--]	[5,000]	[7,000]
Total	248,800	427,564	430,900

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The newly reformulated Mars Exploration Program is pursuing four major goals and objectives:

1) To determine if **life** ever arose on Mars, and if it still exists today
2) To characterize Mars's ancient and present **climate** and climate processes
3) To determine the **geological processes** affecting the Martian interior, crust, and surface
4) To prepare for potential future **human exploration** of Mars, primarily through environmental characterization.

STRATEGY FOR ACHIEVING GOALS

The newly restructured Mars Exploration Program (MEP) will deliver a continuously refined view of Mars with the excitement of discovery at every step. The MEP strategy will respond to new science investigations that will emerge as discoveries are made. The strategy is linked to our exploration experience here on Earth, including experience in deep sea exploration and petroleum deposit searches, and uses Mars as a natural laboratory for understanding life and climate on Earth-like planets other than our own.

The basic scientific approach to achieving these goals is one of "Seek, In-Situ, and Sample". In the initial phases – and relying heavily on orbital instruments – the MEP will survey Mars to identify scientifically interesting areas in global context. Following this phase, more detailed measurements will be made by long-lived assets on the surface, allowing in-situ laboratory analyses to refine the interpretations developed during the previous orbital reconnaissance phase and confirm from the ground the observations made in orbit. Finally, samples of scientifically significant components of the Martian atmosphere, surface, and subsurface will be returned to Earth for definitive analytical investigation in ways that are not possible to be performed on the surface of Mars.

Mars Global Surveyor (MGS), the first of the MEP missions, is an orbiter that carries a science payload comprised of 5 of the original 8 spare Mars Observer instruments aboard a small, industry-developed spacecraft. MGS was launched successfully in November 1996 aboard a Delta II launch vehicle and has been producing highly valuable science output since it arrived at Mars in September 1997. The primary mapping mission concluded successfully on 31 January 2001. Among other discoveries, MGS images have provided potential evidence of recent liquid water flows at or near the surface of Mars.

The '98 Mars Orbiter and Lander consisted of the Mars Climate Orbiter (MCO) and the Mars Polar Lander (MPL). MCO launched in December 1998 and MPL launched in January 1999; however, both missions failed upon arrival at Mars.

One of the Mars 2001 Odyssey Orbiter's primary science objectives is to determine the elemental and chemical composition of the Martian surface. Odyssey will carry 3 science instruments, the Thermal Emission Imaging System (THEMIS), the Gamma Ray Spectrometer (GRS), and the Mars Radiation Environment Experiment (MARIE). THEMIS will map the mineralogy and morphology of the Martian surface using a high-resolution camera and a thermal infrared imaging spectrometer. The GRS will achieve global mapping of the elemental composition of the surface and determine the abundance of hydrogen in the shallow subsurface. The GRS is a rebuild of the instrument lost with the Mars Observer mission. The MARIE will characterize aspects of the near-space radiation environment as related to the radiation-related risk to human explorers. The 2001 Mars Odyssey Orbiter is scheduled for launch in April 2001, and will arrive at Mars in October 2001. Initial scientific data will be acquired starting in January 2002.

The twin 2003 Mars Exploration Rovers' (MERs) goal is to help determine whether water-related minerals exist at or near the Martian surface, and if so, whether they were produced by biological processes or some other mechanism. The MERs are twin robotic field geologists, which will provide the first microscopic study of rocks and soils on Mars. They may discover local evidence for how water once persisted at the surface and what ultimately to search for from orbit. The twin rovers will also have the mobility to travel up to 1000 meters across the Martian landscape, measuring the chemical character of the soils, rocks, and even the previously inaccessible interiors of rocks where unaltered materials may lurk. The MER robotic rovers will be built and operated by NASA's Jet Propulsion Laboratory, with launch currently are planned for May and June 2003. Both rovers will enter Mars' atmosphere and bounce to a stop on the Martian surface in January 2004.

The Future Mars Exploration budget includes the following items:

- Formulation activity (Phase A & B) for the 2005 Mars Reconnaissance Orbiter (MRO). MRO is the ultimate reconnaissance tool in the *Seek, In-situ, and Sample* strategy. MRO will narrow the focus into the localities identified as most promising by MGS and Odyssey, searching for the most compelling environmental indicators that a particular area was once suitable for bearing life (warm, wet, chemically benign, etc.).
- Preformulation phases for Mars missions beyond 2005, including a competitively selected 2007 Mars Scout mission, a highly capable 2007 Mars Smart Lander and Mobile Laboratory mission, and U.S. contributions to foreign Mars missions.
- Mars Technology to lay the groundwork and provide new capabilities for the Mars missions beyond 2005. The Jet Propulsion Laboratory, other NASA centers, and competitively selected industry and academic partners are actively engaged in developing new technology to unlock the mysteries of the Martian climate and geological history. The teams creating Mars exploration

technology combine novel uses of existing technology with cutting-edge advances in new areas of research to develop effective, low-cost solutions. The technology investment in this area will fund precision atmospheric entry and landing techniques, hazard avoidance systems, new in-situ sensors, and other ascent and mobility systems.
- Construction of a Deep Space Network (DSN) 34-meter Beam-Wave-Guide (BWG) Antenna and other DSN upgrades to reduce overloading problem during Mars and other OSS missions' critical activities.

SCHEDULE & OUTPUTS

Mars 2001 Orbiter and Lander

Orbiter & Lander ATLO Start Plan: 1st Qtr FY 2000 Revised: 1st Qtr FY 2000	Begin Assembly, Test and Launch Operations (ATLO) by integrating major components of the spacecraft into the spacecraft structure. Assembly, test and launch operation for the Orbiter mission started on time. However, the assembly, test and launch operations for the Lander did not occur since this mission was cancelled.
Orbiter & Lander Science Instruments Plan: 3rd Qtr., FY 2000 Actual/Revised: Orbiter: 3rd Qtr., FY 2000 Lander: late FY 2001	Deliver Mars 2001 Orbiter and Lander science instruments that meet capability requirements. The Mars '01 Orbiter portion of the target was accomplished; all work is proceeding on schedule to support an April 2001 launch. Orbiter instruments were delivered, and assembly and testing began on time. The Mars '01 Lander was cancelled due to program redesign after the loss of the Mars '98 spacecraft; however, the Lander instruments are to be used on the '03 Lander mission, and will be delivered in late FY01.
Ship Orbiter Plan: 1st Qtr FY 2001 Revised: 2nd Qtr FY 2001	Ship to VAFB launch site. The Odyssey orbiter shipped in January 2001, a one month delay. Additional schedule was provided by the launch site change from VAFB to CCAFS in response Red-Team recommendations.
Ship Lander Plan: 2nd Qtr., FY 2001 Revised: Lander cancelled	Ship to KSC launch site. The Mars '01 Lander was indefinitely postponed due to program redesign after the loss of the Mars '98 spacecraft.
Orbiter Launch Plan: March 2001 Revised: April 2001	Launch on schedule. One-month delay is due to implementation of Red-Team recommendations. (Additional schedule provided by the launch site change from VAFB to CCAFS.)

Lander Launch Plan: April FY 2001 Revised: Lander cancelled	Launch on schedule. The Mars '01 Lander was indefinitely postponed due to program redesign after the loss of the Mars '98 spacecraft. The Mars '01 Lander instruments will be flown on the '03 MERs.
2003 Mars Exploration Rover (MER)	
Mars Exploration Rover '03 Plan: FY 2002	Initiate assembly, test, and launch operations (ATLO) process. Assuming the Mars Exploration Program architecture is confirmed, meet the milestones for the Mars '03 instrument selection and initiate implementation of the Lander mission. Failure of the two Mars '98 spacecraft led to the Mars Surveyor Program redesign. However, milestones for Mars '03 instrument selection and Lander mission implementation have been accomplished.
2005 Mars Reconnaissance Orbiter (MRO)	
Mars Reconnaissance Orbiter '05 Plan: FY 2002	Select payload and initiate development. Deliver engineering models of the radio-frequency subsystem and antennae for the radar sounder instrument to ESA (if ESA approves the Mars Express mission), and select the contractors for the major system elements of the Mars Surveyor '05 mission. Engineering models for Mars Express were shipped two weeks into the new fiscal year (FY01). The Mars Exploration Program architecture was approved in November 2000; selections for the '05 mission are planned for FY 2002.

ACCOMPLISHMENTS AND PLANS

The Mars Surveyor Program completed restructuring activities in November 2000. To reflect the significance in the changes to the program, the Mars Surveyor Program name has been changed to Mars Exploration Program (MEP).

The '98 Mars Climate Orbiter (MCO) and Mars Polar Lander (MPL) launched successfully in December 1998 and January 1999; however, both missions failed upon arrival at Mars.

Spacecraft and instrument development for the Mars 2001Odyssey were completed and the systems were delivered for integration and test in the 4th Quarter of FY 2000. The assembled spacecraft and instruments were shipped to Cape Canaveral in January 2001. Launch is scheduled for April 2001.

The 2003 Mars Exploration Rover (MER) was selected on August 10, 2000. A Preliminary Design Review (PDR) was completed on February 2, 2001, and the project entered Phase C/D on February 25, 2001.

The 2005 Mars Reconnaissance Orbiter (MRO) entered the formulation phase in the 2nd Quarter of FY 2001. A Request For Proposals (RFP) for the spacecraft and an Announcement of Opportunity (AO) for the science instruments will be released during the 3rd. Quarter of FY 2001.

A Request for Proposals (RFP) for construction of the new 34-meter DSN antenna will be released in the 3rd quarter of FY 2001. The Critical Design review (CDR) for the antenna will occur in late calendar year 2002. The antenna construction will begin at Madrid in 2002. Procurements of long-lead-time electronic components, such as recorders and high-power transmitters, will also be initiated in FY 2002. The antenna will become operational in FY 2003, in time to support the MER missions.

BASIS OF FY 2002 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
HST operations	2,100	1,497	1,600
Other mission operations	76,600	83,806	103,700
Total...	78,700	85,303	105,300

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 2001 and September 2002.

Advanced Composition Explorer, ACE (launched August 25, 1997; operations expected beyond FY 2002)
ACE is measuring the composition of the particles streaming from the Sun and of high-energy galactic cosmic rays.

Cassini (launched October 15, 1997; operations expected through ~ 2008)
Cassini will conduct a detailed exploration of the Saturnian system including: 1) the study of Saturn's atmosphere, rings and magnetosphere; 2) remote and in-situ study of Saturn's largest moon, Titan; 3) the study of Saturn's other icy moons; and 4) a Jupiter fly-by to expand our knowledge of the Jovian System. During the transit from Jupiter to Saturn, Cassini will conduct unique radio-science measurements designed to detect ripples of gravitational field produced by catastrophic events in the galaxy. Cassini will arrive at Saturn in 2004.

Chandra X-ray Observatory, CXO / Advanced X-ray Astrophysics Facility, AXAF (launched on July 23, 1999; operations expected through ~ FY 2009)

The objectives of Chandra are to: obtain high-resolution x-ray images and spectra in the 0.1-to-10-KeV wavelength range; investigate the existence of stellar black holes; study the contribution of hot gas to the mass of the universe; investigate the existence of dark matter in galaxies; study clusters and superclusters of galaxies; investigate the age and ultimate fate of the universe; study mechanisms by which particles are accelerated to high energies; confirm the validity of basic physical theory in neutron stars; and investigate details of stellar evolution and supernovae.

Comet Nucleus Tour, CONTOUR (launch scheduled summer 2002; operations expected beyond FY 2002)
CONTOUR will dramatically improve our knowledge of key characteristics of comet nuclei, and assess their diversity, by making close approaches to at least two comets.

Cooperative Astrophysics and Technology Satellite, CATSAT (launch scheduled winter 2001/2; operations expected beyond FY 2002)
CATSAT is a University-class Explorer that will study the origin and nature of Gamma Ray Bursters, one of the most mysterious astrophysical phenomena.

Cosmic Hot Interstellar Plasma Spectrometer, CHIPS (launch scheduled summer 2002; operations expected beyond FY 2002)
CHIPS will use an extreme ultraviolet spectrograph during its one-year mission to study the "Local Bubble," a tenuous cloud of hot gas surrounding our Solar System that extends about 300 light-years from the Sun

Deep Space 1, DS1 (launched October 24, 1998; operations expected to end in FY 2002)
Deep Space 1 has completed 100% of the testing required to validate its new technologies, and the mission has been extended, with a new focus on gathering scientific information during a fly-by of comet Borelly in September 2001.

Far Ultraviolet Spectroscopic Explorer, FUSE (launched June 24, 1999; expected operations beyond FY 2002)
The objectives for the FUSE mission are to measure abundances of deuterium produced by the Big Bang, the Milky Way, and distant galaxies; determine the origin and temperature of galactic gaseous clouds and observe interaction between the solar wind and planetary atmospheres.

Fast Auroral Snapshot, FAST (launched August 21, 1996; operations expected through FY 2001)
FAST is a low-altitude, polar-orbiting 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.

Galaxy Evolution Explorer, GALEX (launch scheduled in 2nd. QTR of FY 2002, expected operations beyond FY 2002)
GALEX will use an ultraviolet telescope during its two-year mission to explore the origin and evolution of galaxies and the origins of stars and heavy elements, and to detect millions of galaxies out to a distance of billions of light-years. GALEX will also conduct an all-sky ultraviolet survey.

Galileo (launched October 18, 1989; operations expected through August 2003)
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 finished its primary mission and began the Galileo Europa Mission (GEM), a detailed study of Jupiter's ice-covered moon. Galileo completed the GEM in January and began its "Galileo Magnetosphere Mission" (GMM]. This extension enabled unique science investigations in coordination with the Cassini fly-by of Jupiter in December 2000, has generated unique engineering data on the performance of the spacecraft in high-radiation-dosage environments, and is providing a detailed study of the volcanic moon IO and the inner Jovian magnetosphere. Galileo will end its mission in August 2003 with a Jupiter Impact.

Genesis (launch scheduled July 2001; operations expected to end in FY 2004)
The Genesis mission will collect samples of charged particles from the solar wind and return them to Earth laboratories for detailed analysis.

High Energy Solar Spectroscopic Imager, HESSI (launch scheduled April 2001, operations expected beyond FY 2002)
HESSI will observe the Sun to study particle acceleration and energy release in solar flares.

High Energy Transient Explorer 2, HETE-2 (launched October 08, 2000; operations expected beyond FY 2002)
The primary goal of HETE-2 is to determine the origin and nature of cosmic gamma-ray bursts.

Hubble Space Telescope, HST (launched April 25, 1990; operations expected 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 and initial science data acquisition 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 and science related flight operations.

Imager for Magnetopause-to-Aurora Global Exploration, IMAGE (launched March 25, 2000, operations expected through FY 2002)
IMAGE will study the global response of the Earth's magnetosphere to the changes in the solar wind.

International Solar-Terrestrial Physics, ISTP: Geotail (launched July 24, 1992; operations expected beyond FY 2002), Wind (launched November 1, 1994; operations expected beyond FY 2002), Polar (launched February 24, 1996; operations expected beyond FY 2002), Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995; operations expected beyond FY 2002), Cluster-II (launched July 16 and August 9, 2000; operations expected beyond FY 2002).

Geotail is a Japan-U.S. spacecraft that is exploring the near-tail region on the night side and the magnetopause on the day side of the Earth. Wind measures the energy, mass, and momentum that the solar wind delivers to the Earth's magnetosphere. Polar provides dramatic images of the aurora and complementary measurements to provide a direct measure of the energy and mass deposited from the solar wind into the polar ionosphere and upper atmosphere. SOHO studies the solar interior by measuring the seismic activity on the surface; SOHO also investigates the hot outer atmosphere of the Sun that generates the variable solar wind, as well as UV and X-ray emissions affecting the Earth's upper atmosphere, the geospace environment, and the heliosphere. The four ESA/NASA Cluster spacecraft are carrying out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions.

Interplanetary Monitoring Platform-8, IMP-8 (launched October 26, 1973; operations expected beyond FY 2002)
IMP-8 performs near-continuous studies of the solar wind and the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

Mars Global Surveyor (launched November 7, 1996; expected operations beyond FY 2002)
MGS studied the Martian topography, seasonal changes, and internal and atmospheric structures for a complete Martian year (March 1999 through January 2001). During its prime mission, MGS collected more information about the red planet than all previous missions combined. MGS completed its primary mission on January 31, 2001, and moved immediately into an extended mission phase. In the extended phase MGS will study the most interesting locations on the planet in detail and observe variability on the Martian surface. MGS will also study potential landing sights for the Mars 2003 rovers.

2001 Mars Odyssey (launch scheduled April, FY 2001; expected operations beyond FY 2002)
The Mars 2001 Odyssey science objective is to determine the elemental and mineral composition of the Martian surface, learn about the landforms, and measure the potential radiation hazards for future human exploration. The 2001 Mars Odyssey Orbiter is scheduled for launch in April 2001, will arrive at Mars in October 2001, and will begin mapping activities 45-to-90 days after orbit capture.

Microwave Anisotropy Probe, MAP (launch scheduled summer 2001, operations expected beyond FY 2002)
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.

Near Earth Asteroid Rendezvous, NEAR (launched February 17, 1996; operations ended February 2001)
NEAR completed its one year orbital mission around the asteroid Eros with a soft landing on the asteroid on February 12, 2001. Initial data analysis will be completed in FY 2001, followed by a competitive Guest Investigator program.

Rossi X-ray Timing Explorer, RXTE (launched December 30, 1995; expected operations beyond FY 2002)
RXTE observes the fast-moving, high-energy worlds of black holes, neutron stars, X-ray pulsars and bursts of X-rays that light up the sky and then disappear forever.

Solar Anomalous and Magnetospheric Particle Explorer, SAMPEX (launched July 3, 1992; operations expected through FY 2002)
SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

Space Infrared Telescope Facility, SIRTF (launch scheduled summer 2002, operations expected beyond FY 2002)
SIRTF, the last of NASA's four Great Observatories, will be a cryogenically cooled observatory to conduct infrared astronomy from space. Incorporating the latest in large-format infrared detector array technology, SIRTF will do for infrared astronomy what the Hubble Space Telescope has done in its unveiling of the visible universe.

Stardust (launched February 7, 1999; expected sample return to Earth in 2006)
Stardust flew by Earth for its final gravity assist in January 2001, and continues on its five-year cruise to rendezvous with Comet Wild-2, in January 2004.

Submillimeter Wave Astronomy Satellite, SWAS (launched December 5, 1998; expected operations through January 2002)
SWAS is designed to study the chemical composition of interstellar gas clouds. Its primary objective is to survey water, molecular oxygen, carbon, and isotopic carbon monoxide emission in a variety of galactic star forming regions.

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics, TIMED (launch scheduled summer 2001; operations expected beyond FY 2002)
TIMED will explore the Earth's Mesosphere and Lower Thermosphere (60-180 kilometers), the least explored and understood region of our atmosphere.

Transition Region and Coronal Explorer, TRACE (launched April 1, 1998; operations expected beyond FY 2002)
TRACE observes, with high resolution, the effects of the emergence of magnetic flux from deep inside the Sun to the outer corona.

Ulysses (launched October 6, 1990; operations expected beyond FY 2002)
Ulysses is transiting the solar poles during 2001, during the peak of the current solar maximum period. The spacecraft is measuring solar wind properties at high latitudes and is providing a unique 3-dimensional perspective of the heliosphere.

Voyager Interstellar Mission (Voyager 1 launched September 5, 1977; Voyager 2 launched August 20, 1977; operations expected beyond FY 2002)
Voyager 1 and 2 are traveling beyond the planets, continuing to probe the outer heliosphere searching for the boundary between the solar system and interstellar space.

NASA also participates in the following international missions. The foreign partners provide for the operations costs of these missions, with NASA providing science contributions.

- **Beppo-SAX (launched April 30, 1996; operations expected beyond FY 2002)**
- **Highly Advanced Laboratory for Communications and Astronomy, HALCA (launched February 12, 1997; operations expected to end FY 2002)**
- **International Gamma-Ray Astrophysics Laboratory, INTEGRAL (launch scheduled April 2002; operations expected beyond FY 2002)**
- **Nozomi (launched July 3, 1998; operations expected beyond FY 2002)**

- **X-ray Spectroscopy Mission, XMM (launched December 10, 1999; operations expected beyond FY 2002)**
- **Yohkoh (launched August 31, 1991; operations expected beyond FY 2002)**

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 of the end of January 2001, there are 24 operational Space Science missions (25 spacecraft), in addition to participation in six foreign missions (nine spacecraft).

At the end of FY 2002,we expect to have 33 operational Space Science spacecraft, in addition to participation in the operations of nine foreign spacecraft. Missions expected to begin operations before the end of FY 2002 include 2001 Mars Odyssey (04/01), HESSI (spring 2001), Genesis (summer 2001), MAP (summer 2001), TIMED (summer 2001), CATSAT (winter 2001/2), GALEX (early 2002), INTEGRAL (spring 2002), CONTOUR (summer 2002), SIRTF (summer 2002), and CHIPS (summer 2002).

TECHNOLOGY CROSSWALK from FY 2001 to FY 2002

FY 2001	FY 2002
SUPPORTING RESEARCH AND TECHNOLOGY	TECHNOLOGY PROGRAM
Core Program	Core Program
Focused Programs	Focused Programs
Astronomical Search for Origins	Astronomical Search for Origins
[Construction of Facilities]	[Construction of Facilities]
Solar System Exploration	Solar System Exploration
Sun-Earth Connections	Sun-Earth Connections
Structure & Evolution of the Universe	Structure & Evolution of the Universe
New Millennium Program	New Millennium Program
Research and Analysis	RESEARCH PROGRAM
Data Analysis	Research and Analysis
Suborbital	Data Analysis
Balloon Program	Suborbital
Sounding Rockets	Balloon Program
	Sounding Rockets

BASIS OF FY 2002 FUNDING REQUIREMENT

TECHNOLOGY PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Technology Program	581,200	419,245	478,800
Core Program	245,200	96,487	108,000
Focused Programs	322,200	301,105	307,000
Astronomical Search for Origins	117,600	111,055	193,500
[Construction of Facilities]	[2,500]	[490]	
Solar System Exploration	156,400	112,421	48,600
Sun-Earth Connections	24,800	52,484	49,100
Structure & Evolution of the Universe	23,400	25,145	15,800
New Millennium Program	13,800	21,652	63,800

PROGRAM GOALS

The goals of the Technology Program are to: (1) lower mission life-cycle costs; (2) provide new scientific capabilities; (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.

STRATEGY FOR ACHIEVING GOALS

TECHNOLOGY

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

Core Programs are comprised of two major components: Space Science Technology and Cross-Enterprise Technology, which has been transferred to the Aero-Space Technology Enterprise in FY 2001 and beyond.

Space Science Technology provides for several activities that cover a broad range of baseline technological capabilities supporting multiple applications. Most of the funding in this area provides for computation and information technologies. Other core capabilities, such as ground system hardware and software for deep space missions, are also included in this area. The elements of the Space Science Technology Program are described below:

- 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 Remote Exploration and Experimentation (REE) project, a part of the NASA High-Performance Computing and Communications Program has been working to develop low-power, fault-tolerant, high-performance, scaleable computing technology for a new generation of microspacecraft. Funding for this activity is ending at the end of FY 2001 as a result of policy and budget prioritization decisions.

- The Planetary Flight Support (PFS) program provides ground system hardware, software, and mission support for all deep-space missions. Planetary Flight Support has recently focused on the design and development of multi-mission ground operation systems for deep space and high-Earth-orbiting spacecraft, including 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.

- Additional funding provided in the President's FY 2002 Budget also supports key In-Space Propulsion technology investments that will enable faster and more capable future planetary missions such as a future sprint mission to the planet Pluto by 2020. Key technologies to be included in this line may include advanced electric and nuclear propulsion systems.

- Other Space Science Core Technology provides funding to those technologies that are applicable to multiple science themes within OSS. Technologies eventually move from this category into a focused program (described below) when they have successfully been demonstrated and are ready for infusion into a focused program mission.

- The Intelligent Systems Program will provide NASA with autonomous and semi-autonomous computational capabilities to enable future missions in deep space, planetary exploration, aerospace applications, and Earth observing systems and data understanding. In FY 2001 the Intelligent Systems Program was transferred to the Aero-Space Technology Enterprise.

Although most of the Cross-Enterprise Technology program was transferred to the Aero-Space Technology Enterprise, a few elements that are critical to Space Science remain here. These remaining activities are Gossamer Spacecraft and Next Decade Planning, as well as the Congressionally mandated Space Solar Power activities.

- The Gossamer Spacecraft initiative supports efforts to develop and demonstrate the deployment, control, and utility of ultra-light, thin-film, deployable structures and space observatories. Technologies developed in this area could support several future applications: solar sail propulsion, large-aperture astronomical observatories, large-aperture remote sensing, large-scale power collection and transmission in space, and interstellar precursor missions.

- Next Decade Planning is supporting intra-agency planning to develop and refine a robust set of potential civil space programs that could be undertaken in the next decade. This planning effort will result in roadmaps that will aid in selecting technologies aimed at enabling these future programs.

- Space Solar Power is developing goals and objectives, detailed roadmaps, and technology investment priorities through ongoing studies and initial technology activities. Although funded in the Space Science budget by Congress, this project is managed by the Office of Space Flight.

Focused Programs are dedicated to high-priority technologies needed for specific science missions. An aggressive technology development approach is used that requires 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 2002 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, Solar System Exploration (formerly known as Advanced Deep Space Systems Development), 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.

- Solar System Exploration (formerly known as Advanced Deep Space Systems Development) provides for the development, integration, and testing of revolutionary technologies for the Outer Planets Program (OPP) and development and launch of missions to the outer planets. Technology funded within this line includes micro-avionics and advanced power systems. Funding for spacecraft currently under development includes the Europa Orbiter (EO) Mission.

- Sun-Earth Connections (SEC) focused program formulates missions to investigate the effects of solar phenomena on the space environment and on the Earth. Missions funded in this area that are now under study include STEREO (funded as a separate major mission beginning in FY 2002; see page SAT 1-23 above), Solar B, and Solar Dynamics Observatory, as well as future SEC missions. The FY 2002 budget includes two programs, Solar Terrestrial Probes Program and Living With a Star. The Solar Terrestrial Probes Program focuses on studying the Sun and Earth as an integrated system to address the scientific questions of how and why the Sun varies and how the Earth and planets respond. Living With a Star, a new program in FY 2001, is a set of missions, analysis, and testbeds designed to develop the scientific understanding of how the connected Sun-Earth system affects life and society. Understanding the connected system becomes more important as we increase our dependence on space-based systems and assets and look toward a future permanent human presence in space. The Living With a Star Program capitalizes upon investments made in the Solar Terrestrial Probes Program in missions such as TIMED, STEREO, and Solar-B as well as the ST-5 nanosat technology validation project in the Flight Validation Program. LWS will also leverage partnerships with other federal agencies.

- Structure and Evolution of the Universe Technology provides for the development of technologies to study the large-scale structure of the universe, including the Milky Way, and objects of extreme physical conditions. SEU missions are aimed at explaining the cycles of matter and energy in the evolving universe, examining the ultimate limits of gravity and energy in the universe and forecasting our cosmic destiny. Technology funded in this area supports missions now under study, such as Herschel (formerly named FIRST) and GLAST (funded as a separate major mission beginning in FY 2002; see page SAT 1-25 above). Additional funding provided in the President's FY 2002 Budget supports technology for development decisions on future SEU missions, particularly Constellation-X and LISA.

Focused Program Missions	Implementation Start	FY 2000	FY 2001	FY 2002
Origins				
SIM	FY 2003	39,225	30,300	30,800
NGST	FY 2004	48,650	45,200	92,100
TPF	FY 2008	4,000	5,500	7,300
Starlight (formerly ST-3)	TBD	8,000	14,500	48,400
Keck Interferometer	FY 1998	13,700	9,800	7,800
Solar System Exploration				
Europa Orbiter	FY 2004	32,500	96,100	48,600
Structure & Evolution of the Universe				
FIRST	FY 2001	16,100	15,500	[14,600]
GLAST	FY 2002	4,900	4,700	[19,400]
Constellation-X	TBD	1,600	1,596	TBD
LISA	TBD			TBD
Sun-Earth Connections				
MMS	FY 2005	400	700	6,500
GEC	FY 2005	100	400	500
MC	FY 2007	100	400	500

The **New Millennium Program** provides a path to flight-validate key emerging technologies to enable exciting science missions. Through the New Millennium Program, high-value technologies are made available for use in the Space Science program without imposing undue cost and risk on individual science missions. This program was restructured to increase its levels of openness and competitiveness, to reduce the size and cost of the missions, and to ensure focus on technology demonstration, versus science data gathering. The program includes validation of both complete systems and subsystems. NASA plans to enable two small ($40-50 million each) and one medium ($100-150 million) system validations every four years, along with two-to-three subsystem validations per year, including carrier and secondary launch. 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.

SCHEDULE & OUTPUTS

Core Program

First-Generation computing testbed Plan: 2nd Qtr FY 1999 Revised: 3rd Qtr FY 2000 Revised: TBD	For HPCC Remote Exploration and Experimentation (REE) program, install first-generation scaleable embedded computing testbed operating at 30-200 MOPS/watt. Difficulties with the hardware design have delayed delivery. *Delivery of the first-generation embedded computing testbed was delayed due to hardware problems. It was delivered in November 2000. Demonstration is expected in late FY 2001. Funding for HPCC/REE was terminated in FY 2002 to support other priorities. The impact of the termination on the completion of this activity is still under examination.*
Demonstrate scaleable computer for spaceborne applications Plan: 3rd Qtr FY 1999 Revised: 4th Qtr FY 2000 Revised: TBD	For HPCC Remote Exploration and Experimentation (REE) program, demonstrate scaleable spaceborne applications on a first-generation embedded computing testbed. *All of the applications have been delivered and demonstrated on a commercial parallel computer and are awaiting delivery of the testbed.* *Delivery of the first-generation embedded computing testbed was delayed due to hardware problems; delivered in November 2000. Demonstration is expected in late FY 2001. Funding for HPCC/REE was terminated in FY 2002 to support other priorities. The impact of the termination on the completion of this activity is still under examination.*
HPCC Plan: FY 2001 Revised: TBD	Demonstrate a real time capability with software-implemented fault tolerance for embedded scalable computers. Real time performance latencies of less than 20 milliseconds are to be sustained at fault rates characteristic of deep space and low-Earth orbit (LEO). *HPCC/REE funding was decreased in FY 2001 to provide support for other OSS priorities. As a result, scheduled completion of this activity was delayed until FY 2002. . Funding for HPCC/REE was terminated in FY 2002 to support other priorities. The impact of the termination on the completion of this activity is still under examination.*

Information Systems Plan: FY 2000 Actual: FY 2000	Information Systems R&T will demonstrate the search, discovery, and fusion of multiple data products at a major science meeting. *Data products were successfully demonstrated at American Astronomical Society (AAS) and American Geophysical Union (AGU) meetings.*
Information Systems Plan: FY 2000 Actual: FY 2000	Information Systems R&T will accomplish and document the infusion of five information systems R&T efforts into flight projects for the broad research community. *Infusion of information systems R&T efforts included: (1) Computational tools developed under AISRP, which were used for BOOMERANG and MAXIMA data analysis; (2) Physics-based modeling/simulation, which was used for MICAS camera on DS-1; (3) PIXON method image reconstruction, which was used for Chandra and other flight mission data; (4) Precision Mining of Hyperspectral Data, which was applied for Mars mission data analysis; (5) SkyView virtual telescope capability, which was incorporated into mainstream HEASARC data center services; and (6) Science Expert Assistant, which was adopted by STScI for production use with HST observing program.*
Information Systems Plan: FY 2001 Revised: FY 2001 and FY 2002	Information Systems R&T will demonstrate Virtual Observatory capability from an investigator workstation for multi-wavelength discovery, analysis and visualization across a collective set of space and ground astronomical surveys; and will demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of Mars '03 and '05 missions. *Virtual Observatory demonstration will be completed in FY 2001. However, the Virtual Mars demonstration will not be completed until FY 2002, due to reallocation of funding to higher priority projects.*
Explorer Program Technology Plan: FY 2001	Complete 45 Explorers Technology Investigations selected in FY99. *These 45 investigations are funded; 43 have been completed. All 45 selected investigations will be completed by the 3rd quarter of FY 2001.*
Explorer Program Technology Plan: FY 2001	Implement awards for additional investigations planned for selection in FY 2000. *The FY00 Explorer NRA was not released due to redirection of funding to Explorer missions to address issues identified by Red Team reviews.*

Cross-Enterprise Technology:
Develop Wide-Band Low-Power Electronically-Tuned Local Oscillator Sources up to 1.3 THz
Plan: 3rd Qtr FY 1998
Revised: 3rd Qtr FY 2000
Actual: 4th Qtr FY 2000

A wide-band local oscillator (with 15% bandwidth) has been demonstrated operating at frequencies up to 0.5 THz. Construction of components operating at higher frequencies is underway. Lab demonstration of local oscillators operating at frequencies up to 1.9THz is planned for 3RD Qtr FY 2000.

Technology approach and development schedule changed to reflect new advances in amplifier technology. Baselined technology on FIRST mission.

Cross-Enterprise Technology:
Task Selections
Plan: 4th Qtr FY 2000
Actual: 1st Qtr FY 2001

Select first set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.
Selected 111 technologies from among 1229 proposals.

Cross-Enterprise Technology:
Task Selections
Plan: FY 2001
Revised: N/A

Select second set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.
Program management and funds transferred to the Office of Aerospace Technology, effective October 1, 2000.

Cross-Enterprise Technology:
Full and Open Competition
Plan: End of FY 2000
Revised: FY 2001

One hundred percent of tasks subjected to full and open competition and/or external non-advocate review by end of FY 2000.
Program currently responding to Congressional inquiry; change in approach to percentage of competition.

Focused Programs

Astronomical Search for Origins

Starlight (formerly ST-3)
System Architecture Review
Plan: August 1999
Revised: October 2000
Revised: FY 2001

System Architecture & Requirements Review.
Delay due to significant program rephasing and replanning to bring ST-3 and TPF schedules into alignment, resulting in extended Phase B for ST-3.

Starlight (formerly ST-3) Technology Development
Plan: FY 2001
Revised: PDR FY 2002
CDR FY 2003

Successfully complete PDR as well as project and spacecraft CDR.
Delay due to significant program rephasing and replanning to bring ST-3 and TPF schedules into alignment, resulting in extended Phase B for ST-3.

Space Interferometry Mission (SIM) Non-Advocate Review
Plan: 2nd-4th Qtr FY 1999
Revised: 1st Qtr FY 2002
Revised: TBD

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.
Study of revised mission concepts is underway; the schedule for a NAR cannot be determined until this activity is completed.

SIM Nulling Demonstration
Plan: FY 2001
Actual: N/A

Demonstrate stabilization for nulling to one nanometer. Nulling is required to remove starlight that would wash out SIM's view of planets in other solar systems.
Decision made in October 2000 to eliminate the requirement for nulling demonstration in space by SIM. A ground demonstration of <10 nanometers which eliminated the need for additional space and ground nulling demonstration for SIM.

SIM Testbed Demonstration
Plan: FY 2002

Use the Microarcsecond Metrology (MAM-1) Testbed to demonstrate metrology at the 200-picometer level with white light fringe measurements. Accomplishing this level of performance is required in order for SIM to identify multi-planet solar systems out to 10 parsecs.

SIM SRR
Plan: FY 2001
Revised: TBD

Complete System Requirements Review (SRR) and, initiate Phase B
Study of revised mission concepts is underway; the schedule for SRR and Phase B initiation cannot be determined until this activity is completed.

Keck Fringe Detection
Plan: FY 2000
Revised: FY 2001

Development of the interferometer program for connecting the twin Keck 10-meter telescopes with an array of four two-meter class outrigger telescopes will be tested by detecting and tracking fringes with two test siderostats at two- and ten-micron wavelengths.
Replace the entire italicized explanation with: Deliveries of all hardware items to the Keck site on Mauna Kea occurred on time. However, installation of these components into a working system took longer than expected, due to a number of technical problems (e.g., relay mirror optics alignment, optical bench vibration amplification) that had not occurred in the lab at sea level.

Keck Technology Development
Plan: FY 2001

Combine 2 Keck telescopes; install first outrigger telescope.
Efforts to combine the 2 telescopes continue on schedule. However, delays have been encountered in the permitting process for the outrigger telescope. [State and federal level permits required; federal

Revised: Outrigger: TBD	*includes National Environmental Protection Act (NEPA) and National Historic Preservation Act (NHPA) requirements.]*
NGST Technology Testbed Development Plan: FY 2000 Revised: N/A (approach altered)	Complete the NGST Developmental Cryogenic Active Telescope Testbed (DCATT) phase 1, measure ambient operation with off-the-shelf components, and make final preparations for phase 2, the measurement of cold telescope operation with selected "flight-like" component upgrades. *These technologies are critical to the operation and optimization of segmented optics, which we envision will be used by NGST and other telescopes. DCATT Phase 0 was successful. However, Phase 1 was not successful due primarily to problems with the segmented 1-meter telescope addition. As a result of these problems, the wavefront sensing and control effort was changed (both management and testbed approach) in October 1999 to correct the problems in the original DCATT effort. The new program involves a mix of in-house work and efforts by the prime industry teams to develop a series of Wavefront Control Testbeds (WCT) that develop, test and validate algorithms and processes for wavefront control.*
NGST Inflatable Sun Shield Development Plan: FY 2001 Revised: ISIS: cancelled	Inflatable Shield in Space (ISIS) ready to fly on Shuttle; release Announcement of Opportunity (AO) for Science Instrument; down-select to a single Phase 2 prime contractor. *ISIS cancelled after determination that technology would not be necessary for NGST.*
TPF Technology Development Plan: FY 2000 Revised: FY 2002	Complete and deliver a technology development plan for the Terrestrial Planet Finder (TPF) mission. This infrared interferometer requires the definition of technologies that will not be developed or demonstrated by precursor missions. *As part of an overall restructuring of the Origins program, the projected launch date for TPF was moved out two years to 2012 and NASA HQ readjusted the budget guidelines. As a result, the pre-project activities were replanned by JPL. Architecture definition studies were initiated in the 2Q of FY 2000 and the technology roadmap development was postponed until after these studies are completed in the 2nd Qtr. of FY 2002. As a result of HQ decisions to delay the TPF mission and the project replanning, the technology development roadmap will not be completed until FY 2002.*
TPF Architectural Definition Plan: FY 2001 Actual: FY 2000	Award architectural definition contracts. *Contracts were awarded in FY 2000 for Phase 1, with an option for Phase 2 studies. Phase 1 concepts were presented in December 2000. In January 2001, four of these were selected for Phase 2.*
TPF Phase 2 Industrial Contracts Plan: FY 2001 Actual: N/A	Develop RFP for second phase of industrial contracts. *Architectural definition contracts awarded in FY 2000 were for Phase 1, with an option for Phase 2 studies. (See above.) Phase 1 concepts were presented in December 2000. In January 2001, four of these were selected for Phase 2.*
TPF Starlight Nulling	Test Starlight nulling breadboard.

Plan: FY 2001	
TPF Architecture Plan: FY 2002	Provide studies and integrated models of mission architecture concepts.

Solar System Exploration

CISM Technology Plan: 3rd Qtr FY 2000 Revised: FY 2002	Deliver first engineering model of an integrated avionics system. *Although some elements of command and data handling were delivered, the remainder of the technology activity represented by the target is now being reformulated under the Outer Planets Program. The CISM effort has been realigned to development of lower level technology (Technology Readiness Levels 3 to 6).*
CISM Technology Plan: FY 2001	Demonstrate and deliver prototype advanced power transistor [0.35 micron SOI (Silicon On Insulator) CMOS (Complementary Metallic Oxide Semiconductor)].
CISM Active Pixel Sensor Plan: FY 2001 Actual: FY 2001	Demonstrate Active Pixel Sensor with advanced processing capabilities on a single chip. *Demonstration completed.*
X-2000 Technology Development Plan: FY 2000 Revised: FY 2002	The first engineering model (EM-1) of the X2000 First Delivery will be delivered. Successful development includes the integration of all EM-1 hardware, the functional verification of delivered hardware and software, and the ability to support ongoing testing, hardware integration, and software verification for delivered software. *Reformulation of the Outer Planets Program has now integrated the X2000 technology development activity into the Europa Orbiter Project. Delays to date in the X2000 have primarily been the result of design complexity and difficulty in integrating commercial intellectual property into the custom designs necessary to endure the extreme radiation expected in the space environment. In accordance with the reformulated schedule for the Europa Orbiter Project, the anticipated delivery date has moved to late FY 2002.*
X-2000 Technology Development Plan: FY 2001 Revised: FY 2002 for Engineering Model and FY2004 for Flight Hardware	Deliver engineering model and flight set of avionics. *Reformulation of the Outer Planets Program has now aligned the X2000 technology activity into the Europa Orbiter (EO) development effort. The anticipated delivery schedule for the engineering model avionics is now FY 2002, in accordance with the reformulated EO Project schedule. The delivery of flight avionics in support of the baselined 2008 EO launch is now scheduled for FY 2004.*

Solar System Exploration (non-Mars) First Mission C/D Start Plan: 1st Qtr FY 2001 Revised: TBD	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. ***Pluto-Kuiper Express:*** *Preliminary Design Review (PDR) was initially delayed due to increases in spacecraft mass and power resulting in the need for a larger launch vehicle. Concerns were also identified regarding launch vehicle qualification for launch of a spacecraft with a radioisotope power system. Mission life-cycle cost estimates exceeded available budget for a planned December 2004 launch. The project was not ready to proceed into development. A stop-work order was issued in September 2000.* ***Europa Orbiter:*** *Preliminary Design Review (PDR) delayed due to concerns in spacecraft mass, power, and avionics subsystems, and launch vehicle qualification for launch of a spacecraft with a radioisotope power system. Continued engineering design for avionics and power systems. Technology developments in power and avionics subsystems are anticipated to support a FY 2008 planned launch.*
Europa Orbiter Avionics Engineering Model I&T Plan: July 2000 Revised: 2002	Begin integration and test of the Avionics Engineering Model. *The schedule to begin integration and test of the Europa avionics engineering model is now FY 2002, in accordance with the reformulated Europa Orbiter Project schedule.*
Future Deep Space Systems Planning Plan: FY 2001	Deliver X-2000 Level 1-3 Requirements Documents, define subsystems, complete definition of system architecture.
Future Deep Space Multi-Functional Structures Plan: FY 2001 Actual: FY 2001	Demonstrate intermediate-level multi-functional structures (MFS). *Demonstration complete.*
Outer Planets Program Evaluation Plan: FY 2002	Complete evaluation and restructuring of Outer Planets Program.

SEC

Deliver Solar-B Electrical Engineering Models Plan: September 2000 Revised: June 2001	Complete and deliver for testing Solar-B's four Electrical Engineering Models. *As requested by the Japanese, delivery was delayed until June 2001 due to a Japanese-initiated launch delay. (Note: There was a typographical error in the original metric ; only three instruments were planned.)*
Deliver Solar-B Telescope Engineering Model Plan: FY 2001 Revised: FY 2002	Deliver engineering model of the optical telescope and x-ray telescope. *Delayed one year due to Japanese-initiated launch delay. (See above.)*
STEREO Technology Development Plan: FY 2000 Revised: FY 2001	Complete STEREO Phase A studies by June 2000, including the release of an AO for investigations with specific instruments and selection of the formulation phase payload. *AO was released. Specific instruments and the formulation phase payload were selected, and all included international Co-Investigators. Phase A studies were not completed. International Traffic in Arms Regulations (ITAR) requirements were tightened after the AO was issued; therefore, it was not possible to establish all of the necessary Letters of Agreement (LOAs) with foreign governments in time to avoid delaying completion of Phase A studies until FY 2001.*
STEREO Technology Development Plan: FY 2001	Successfully complete Phase B effort, including Confirmation Review.
Complete Living With a Star Strategic Plan Plan: March 2001 Actual: August 2000	Complete Living With a Star Project Strategic Plan, including mission architecture, for the OSS Strategic Plan.
Future ST Probes Technology Development Plan: FY 2001 Actual: January 2001	Complete preliminary concept definitions for spacecraft systems and instruments for Magnetospheric Multiscale.
Living With a Star/SDO Plan: FY 2002	Release AO (Announcement of Opportunity) for Solar Dynamics Observatory (SDO) mission.

SEU

Herschel (FIRST) Instrument Performance Plan: FY 2000 Revised: FY 2001	Demonstrate performance of the Superconductor-Insulator-Superconductor (SIS) mixer to at least 8hv/k at 1,120 GHz and 10hv/k at 1,200 GHz. The U.S. contribution to the ESA Herschel (FIRST) is the heterodyne instrument, which contains the SIS receiver. *Development of required local oscillator is late due to late delivery of a piece of test equipment, ordered from a German company. Expected to be accomplished by mid-FY 2001.*
Herschel (FIRST) Technology Development Plan: FY 2001 Actual: cancelled	Complete the qualification mirror (QM) fabrication. *The U.S. Herschel telescope activity was cancelled due to increased costs to meet additional ESA requirements, as well as cost increases in other, higher priority, SEU programs. ESA had requested the construction and delivery of a FIRST engineering model telescope, which would have increased NASA's costs by approximately $5 million. Moreover, increases in the costs of other, higher priority SEU activities reduced the amount of funds available for U.S. participation in the Herschel telescope activity. ESA has been developing an alternate telescope technology for several years, which ESA now feels can meet Herschel requirements; therefore, continuation of the U.S. telescope activity was not critical to success of the program.*
Herschel Technology Development Plan: FY 2002	Complete the Spectral and Photometric Imaging Receiver (SPIRE) qualification model detectors.
GLAST Prototype Instrument Performance Plan: FY 2000 Actual: FY 2000	The prototype primary instrument for GLAST will demonstrate achievement of the established instrument performance level of angular resolution of 3.5 degrees across the entire 20-MeV (million electron volts) to 100-GeV (giga-electron volts) energy range. *A prototype GLAST instrument was constructed and successfully operated in a beam test in December 1999/ January 2000. Analysis of this data and comparison with detailed computer simulations demonstrate performance as expected. [However, the metric as stated is in error. It should read "less than 3.5 degrees at 100-MeV;" The detector was not tested at 20-MeV. (Reference GLAST AO 99-OSS-03, table 1).]*
GLAST Technology Development Plan: FY 2001	Conduct successful NAR for instrument development, project definition, and interface development.
GLAST Technology Development Plan: FY 2002	Conduct Large-Area Telescope Preliminary Design Review (PDR).

New Millennium Program

ST-5 Critical Design Review Plan: FY 2001 Revised: FY 2002	Complete ST-5 Critical Design Review. *Delayed due to difficulty in securing secondary launch vehicle.*
ST-6, ST-7, and ST-8 Project Selections Plan: FY 2001 Actual: January 2001	Competitively select two-to-three subsystem technology demonstrations. *Eight subsystem technologies have been competitively selected for Phase A study.*
ST-6 and ST-7 Project Approval Plan: FY 2001	Complete ST-6 and ST-7 project approval.
ST-6 Confirmation Review Plan: FY 2002	Conduct ST-6 Confirmation Review.
ST-6 Critical Design Review Plan: FY 2001 Revised: FY 2002	Complete ST-6 Critical Design Review (CDR). *The metric for ST-6 Project Approval (above) was established in the FY 2001 narratives. This CDR metric, also listed in the FY 2001 narratives, was an error; project approval and CDR would not have been planned for the same fiscal year.*
New Millennium Carrier-1 (NMC-1) Confirmation Review Plan: FY 2002	Conduct New Millennium Carrier-1 (NMC-1) Confirmation Review.

ACCOMPLISHMENTS AND PLANS

Core Program

The Information Systems program will continue to provide reliable access for research communities and the public to obtain science data through the National Space Science Data Center and other discipline-oriented data centers. Continuing advances in development and infusion of evolving information technology will increase the level of interoperability to support interdisciplinary research.

The Intelligent Systems program completed a Non-Advocate Review (NAR) in FY 2001. The program has been transferred to Aero-Space Technology Enterprise in FY 2001 and beyond.

In High Performance Computing and Communication, the Remote Exploration and Experimentation project will support the development of a first-generation testbed for scaleable spaceborne applications as well as embedded scaleable high-performance computers. Funding for this activity is ending in FY 2001 as a result of policy and budget prioritization decisions.
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 improved efficiency will allow us to continue to reduce mission operations costs.

A competitive NASA Research Announcement (NRA) will be released in FY 2002 to provide for full participation of industry, academia and other government agencies in key In-Space Propulsion technology activities.

In FY 2000 the Decadal Planning Team (DPT) refined the integrated human and robotic strategy for achieving the new science and discovery grand challenges. Work included conducting technology feasibility assessments; conducting systems and architectures analyses of stepping stone capabilities; developing technology roadmaps and attendant gap analyses to meet the stepping stone capabilities; and assessing the benefits to both the Agency and non-Agency programs from investment in DPT technologies.

In FY 2001, the DPT is proceeding to develop the requirements to guide the Agency's technology investment priorities and initiate technology development by leveraging several existing Agency technology programs. Work will continue on high-priority tasks in system and architecture analyses and technology roadmapping, particularly in-space transportation. These tasks are necessary to define decision criteria for future decision-makers on major Agency human and robotic investments.

In FY 2002, the DPT plans to begin implementation of technology development for the highest priority technologies including in-space transportation, bioastronautics, materials research, and other approved technology areas.

The Cross Enterprise Technology Development Program (CETDP) NASA Research Announcement (NRA) was released during the first quarter of FY 2000. Following the peer-reviewed competition, 111 technologies were selected for award, out of 1229 proposals. In FY 2001 Crosscutting Technology has been transferred to Aero-Space Technology Enterprise.

Focused Programs

The **Astronomical Search for Origins** focused program will fund mission design and technology development for six elements in FY 2001 and 2002:

- An interferometry technology validation flight, StarLight (formerly ST-3), to demonstrate the concept of separated-spacecraft interferometry. StarLight will utilize two spacecraft to validate precision formation flying and space interferometry, technologies that are required for the Terrestrial Planet Finder (TPF) mission (see below).

- The Space Interferometry Mission (SIM) will be the world's first long-baseline operational optical space interferometer. It is scheduled for launch late this decade, 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.

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

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

- 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. TPF is currently planned for launch early next decade.

- 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 **Solar System Exploration** focused program (previously called Deep Space Systems Development) will continue to provide for the development, integration, and testing of revolutionary technologies and missions for the Outer Planets Program (OPP). The funding identified for the Solar System Exploration focused program supports Europa Orbiter and technologies aimed at future OPP missions.

- Europa Orbiter (EO) will study Jupiter's fourth largest moon, Europa, which has attracted immense interest because of indications that a liquid ocean may lay underneath its icy crust. The EO mission is to confirm the existence of a subsurface ocean and study its characteristics. The EO mission will complete its grass-root cost analysis by March 2001 and complete its Independent Assessment (IA) by 4th quarter FY 2001. EO Phase 1 avionics hardware will be delivered by FY 2002.

- Technology development to be funded within the Solar Systems Exploration focused program will support the OPP missions (i.e., EO and other potential OPP missions). Technologies in this line may include Advanced Radioisotope Power Source (RPS), Center for Integrated Space Microsystems (CISM), and other Exploration Technologies. These technologies are currently under a Zero-Based Budget review to determine their feasibility and their applications to the OPP. The zero-based budget review will be completed by the 3rd quarter of FY 2001, and a plan for the content of the FY 2002 technology program will be announced at that time.

The focus for **Sun-Earth Connections** mission planning and technology activities, including both the Solar-Terrestrial Probes and Living With a Star programs, will be directed toward the following future missions:

- Solar-B is a joint mission with the Japanese (ISAS spacecraft and launch). NASA is to provide optical, EUV, and X-ray instrument components for the ISAS-led mission to measure the Sun's magnetic field and UV/X-ray radiation. Funding for this project moved to the Payload and Instrument Development program in FY 2001 (see page SAT 1-XX above).

- STEREO is a mission to understand the origin of mass ejections from the Sun's corona and their consequences, including intense solar energetic particle events. The mission is conceived as two spacecraft in solar orbit that provide stereo imaging of solar corona, track solar mass ejections from the Sun to the Earth using radio and optical instruments, and measure the solar wind and energetic particles. STEREO's anticipated launch date is December 2004. Funding for STEREO is broken out separately as a major development project, beginning in FY 2002 when the project is scheduled to begin implementation (see page SAT 1-XX above).

- Magnetospheric Multiscale is a mission with four spacecraft in elliptical orbits around the Earth to study the interaction of the solar wind with the Earth's magnetosphere. Its launch is planned in 2007.

- Global Electrodynamics Connection is a mission with four Earth-orbiting and dipping spacecraft that will investigate the transition region between the magnetosphere and dense atmosphere, the area that may be important in the Earth's electric field circuit. It is a region where there is a continual tug-of-war between magnetosphere- and lower atmosphere-driven dynamics. Its launch is planned in 2008.

- Magnetospheric Constellation is a network of 10-100 nanosats in Earth orbit to investigate the plasma and fields in the Earth's magnetotail and the linkage between the plasma and fields and the solar wind. Its target launch date is 2010.

- Solar Dynamics Observatory (SDO), a follow-on to Yohkoh, will observe the Sun's dynamics to help us understand the nature and source of the Sun's variations, from the stellar core to the turbulent solar atmosphere. Its launch is planned in late 2006.

- The Radiation Belt Mapper and Ionospheric Mapper missions will provide a network of measurements around the Earth to increase our understanding of origin and dynamics of the radiation belts and ionosphere, thereby increasing our understanding of how the Earth responds to solar variability. The target launch dates are 2009.

- The Solar Sentinel missions will provide a global view of the heliosphere and describe the transition and evolution of eruptions and flares from the Sun to Earth. The target launch dates are 2008 and 2009.

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. Funding for GLAST is broken out separately, as a major development project, beginning in FY 2002, when the project is scheduled to begin implementation (see page SAT 1-22 above).

- On the 200th anniversary of the discovery of infrared light by William Herschel, ESA's Far Infrared and Submillimeter Space Telescope (FIRST) was re-named Herschel Space Observatory. The U.S. participation on the Herschel mission substantially enhances the science goals with four key technologies: cryocoolers, bolometer arrays, and heterodyne receivers. U.S. participation in the development of the mission will be limited to instruments, as U.S. funding is limited, and ESA has technologies available to meet the telescope requirements. Funding for Herschel is included in the Payload and Instrument Development budget beginning in FY 2002 (see page SAT 1-24 above).

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

- Laser Interferometer Space Antenna (LISA). LISA will be a joint NASA-ESA mission to detect and study gravitational wave signals from massive black holes. This includes both transient signals from the terminal stages of binary coalescence (bursts) and binary signals that are continuous over the observation period. Technology funding will support decisions on future mission development.

New Millennium

A constellation of three small satellites called the Nanosat Constellation Trailblazer mission was selected in August 1999 as the Space Technology-5 (ST-5) demonstrator. Each Trailblazer spacecraft will be an octagon 16 inches across and 8 inches high, and each will have booms and antennas that will extend after launch. Results from the Trailblazer mission will be used to design future missions using constellations of lightweight (about 44 pounds), highly miniaturized autonomous spacecraft During fiscal year 2000, ST-5 completed both their mission requirements and system concepts reviews. Confirmation Review will take place in fiscal year 2001, followed by development in fiscal year 2002.

A Technology Announcement for the Space Technology-6 (ST-6) subsystem technology validation opportunity was issued in October 2000. Eight technologies ranging from revolutionary low-power electronics to a continuously operating helium dilution cooler were competitively selected in January 2001 for concept development (Phase A study). ST-6 down-selection is planned for late FY 2001/early FY 2002, where it is anticipated that three to five of the technologies will be competitively selected for ST-6 flight validation in calendar years 2003 and 2004. Pre-concept definition studies for Space Technology-7 (ST-7), a small system validation opportunity, were initiated in January 2001. NASA plans to solicit and competitively select technologies for ST-7 concept definition during FY 2001. Feasibility studies (pre-phase A) were initiated for the New Millennium Carrier (NMC)-1 Space Technology Carrier (STC) in FY 2001 to explore access-to-space options for stand-alone subsystem technology validation.

BASIS OF FY 2002 FUNDING REQUIREMENT

RESEARCH PROGRAM

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Research Program	567,450	596,773	606,500
Research and Analysis	239,450	244,661	246,200
Data Analysis	291,100	310,504	319,200
Suborbital	36,900	41,608	41,100
Balloon Program	13,300	15,266	14,000
Sounding Rockets	23,600	26,342	27,100

PROGRAM GOALS

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

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

The principal goal of the Suborbital program is to provide frequent, low-cost flight opportunities for space science researchers 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 that may ultimately fly on orbital spacecraft, thus reducing cost and technical risks associated with the development of future space science missions. It is also the primary opportunity for training graduate students and young scientists in hands-on space flight research techniques.

STRATEGY FOR ACHIEVING GOALS

RESEARCH AND ANALYSIS

The Space Science Research and Analysis Program carries out its goals and objectives by providing grants to non-NASA research institutions throughout the Nation and the world, as well as by funding scientists at NASA Field Centers. Approximately 1,500 grants are awarded each year after a rigorous peer-review process; only about one out of four proposals is accepted for funding, making this research program among the most competitive in government. This scientific research is the foundation of the Space Science Enterprise. Key research activities include the analysis and interpretation of results from current and past missions; synthesis of these analyses with related airborne, suborbital, and ground-based observations; and the development of theory, which yields the scientific questions to motivate subsequent missions. The Research and Analysis Program also develops new types of detectors and other scientific instruments. Many of these new instrument concepts are tested and flown aboard sounding rockets or balloons. 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. Currently, with the exception of a proprietary period of up to one year for some missions, 100% percent of the data from current and past Space Science missions is openly available to the public via the internet. In the future, these proprietary periods will be phased out completely.

The Enterprise NRA for Research Opportunities in Space Science (ROSS) solicits proposals for basic investigations to seek to understand natural space phenomena across the full range of space science programs relevant to the four OSS science themes. Participation in this program is open to all categories of U.S. and non-U.S. organizations including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Minority and disadvantaged institutions are particularly encouraged to apply. Recommendations for funding are based on the independent evaluation of each proposal's science and technical merits, and its relevance to the Space Science Enterprise objectives as described in the NRA.

DATA ANALYSIS

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.

SUBORBITAL

The Suborbital program provides the science community with a variety of options for the acquisition of in-situ or remote sensing data. Aircraft, balloons and sounding rockets provide access to the upper limits of the Earth's atmosphere. Activities are conducted on both a national and international cooperative basis.

Balloons provide a cost-effective way to test flight instrumentation in the space radiation environment and to make observations at altitudes above most of the water vapor in the atmosphere. In many instances, it is necessary to fly primary scientific experiments on balloons, due to size, weight or cost considerations, or to the 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 GSFC Wallops Flight Facility (WFF) manages the Balloon contract. The National Scientific Balloon Facility (NSBF), a government-owned, contractor-operated facility in Palestine, Texas, conducts flight operations.

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

Sounding rockets are uniquely suited to perform low-altitude measurements (between balloon and spacecraft altitude) and to measure vertical variations of many atmospheric parameters. Sounding rockets are used to support special areas of study, such as: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including aurora production and energy coupling into the atmosphere; and the nature, characteristics and spectra of radiation of the Sun, stars and other celestial objects. In addition, sounding rockets allow several science disciplines to flight-test instruments and experiments being developed for future space missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Launch operations are conducted from facilities at WFF, Virginia; White Sands, New Mexico; and Poker Flat, Alaska, as well as occasional foreign locations. A performance-based contract was awarded February 1999 to allow the government to transition away from operational control. The contract is managed by the GSFC/WFF.

SCHEDULE & OUTPUTS

Space Science Research and Analysis

Issue FY 2000 NASA Research Announcement (NRA) Plan: February 2000 Actual: February 2000	Issue FY 2000 NRA for Research Opportunities in Space Science (ROSS). *The AO was released on February 9, 2000, and is publicly available at http://spacescience.nasa.gov/research/closed00.htm.*
Issue FY 2001 NASA Research Announcement (NRA) Plan: 2nd Qtr., FY 2001 Actual: 2nd Qtr, FY 2001	Issue FY 2001 NRA for Research Opportunities in Space Science (ROSS). *The AO was released on January 26, 2001, and is publicly available at http://spacescience.nasa.gov/research*

Astrobiology Research Plan: FY 2001	High-priority studies identified in the Astrobiology Roadmap will be carried out, the National Astrobiology Institute will conduct institute-wide functions using internet/video conferencing capabilities (i.e. Executive council meetings, science seminars, group collaborations, education/outreach), and Institute research publications will reflect its interdisciplinary nature.

Suborbital Program

Balloon Program

Balloon Flights Plan: FY 2000 Actual: (N/A)	Plans call for 26 worldwide balloon missions. *Twenty-one missions were flown in FY 2000, including two balloons that failed to achieve their required altitude and distance. For two of the missions that did achieve required altitude and distance, investigators' instrumentation failed to function as planned. It should be noted that one of the balloons that failed to reach required altitude was a test flight of a new balloon development. The result was re-design and development of the balloon, which was successfully tested in FY 2001.*
Balloon Flights Plan: FY 2001	Achieve launch success rate of 80% for balloon flights.

Sounding Rockets

Sounding Rocket Flights Plan: FY 2000 Actual: (N/A)	Plans call for 25 worldwide sounding rocket missions. *The increased programmatic costs of the privatization of sounding rocket operations in FY 1999 were not reflected in the FY 2000 budget. Seven sounding rocket missions were moved out of FY 2000 into later years, leaving a goal of 18 planned missions for the year. Sixteen missions were launched, including two failures to achieve the required altitude and orientation. Two other missions failed to meet their minimum success criteria.*
Sounding Rocket Flights Plan: FY 2001	Achieve launch success rate of 80% for sounding rocket flights.

ACCOMPLISHMENTS AND PLANS

Research and Analysis

Our R&A program continued to produce exciting scientific results in 2000. The program supported many of the recent discoveries of planets around other stars. Particularly exciting was the discovery of increasing numbers of planets with masses equivalent to one Jupiter or less. By the end of 2000, the number of known planets around other stars reached over 50. While the potential detection of Earth-like planets remains in the future, per our plans for the Origins program, these R&A-funded results increase the likelihood that such planets may be common in the universe, and are already leading to advances in theoretical models of planetary system formation.

The Near-Earth Object (NEO) Program Office at JPL continues to focus on the goal of locating at least 90 percent of the 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 were to hit the Earth. Detection, tracking, and characterization of such objects are all critical. As additional telescopes and improved detectors have been added to the search, the detection rate has continued to increase. Current estimates (based on a statistical analysis of the objects located to date) are that approximately half of the NEO's have been located.

In recognition of the interrelationship between the origin and evolution of life and the origin and evolution of planets, a new program within the framework of Astrobiology was initiated in 1997. A multi-disciplinary Astrobiology Institute was established with members from 11 geographically distributed research institutions, linked through advanced telecommunications. Examples of research accomplishments for the past year include a genetic study demonstrating that the ancestors of major groups of animal species may have begun populating Earth 1.2 billion years ago, more than 600 million years earlier than indicated by their fossil remains. It was demonstrated that methanogenic bacteria could grow in conditions simulating the subsurface of Mars if even a small amount of water is available. And a microbial world was discovered hidden deep beneath the frozen Antarctic ice; this could help us learn more about how life can survive under extreme conditions on other planets or moons.

Data Analysis

NASA's Space Science spacecraft continue to generate a stream of scientific discoveries. Many of these findings are of broad interest to the general public, as demonstrated by widespread media coverage. Recent highlights include results from Hubble Space Telescope, the Chandra X-ray Observatory, the Near Earth Asteroid Rendezvous (NEAR), Mars Global Surveyor, Cassini, Galileo, Transition Region and Coronal Explorer (TRACE), and the Solar and Heliospheric Observatory (SOHO). 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 just a few of the top science stories of the past year from NASA Space Science missions.

- Imaging scientists using data from Mars Global Surveyor found features that suggest there may be current sources of liquid water at or near the surface of the Red Planet. If verified, this finding clearly increases the possibility that life may still exist on Mars. The finding would also be important for the planning of future human missions to the Red Planet.

- A week's advance warning of potential bad weather in space is now possible thanks to the Solar and Heliospheric Observatory (SOHO) spacecraft. SOHO scientists have, for the first time, imaged solar storm regions on the side of the Sun facing away from the Earth.

- Layers of sedimentary rock paint a portrait of an ancient Mars that long ago may have featured numerous lakes and shallow seas, say Mars Global Surveyor imaging scientists.

- Giant fountains of fast-moving, multimillion-degree gas in the outermost atmosphere of the Sun have revealed an important clue to a long-standing mystery -- the location of the heating mechanism that makes the corona 300 times hotter than the Sun's visible surface. These results came from TRACE.

- Scientists used Chandra to examine a mid-mass black hole in the galaxy M82. This black hole may represent the missing link between smaller stellar black holes and the supermassive variety found at the centers of galaxies.

- A HST census finds that the mass of a supermassive black hole is directly related to the size of a galaxy's nuclear bulge of stars. This suggests that the evolution of galaxies and their host black holes is intimately linked, and has implications for the history of the very early Universe.

Suborbital Program

In FY 2000, 21 balloons were flown for the core program, of which 17 were successful flights. The balloon-borne BOOMERANG sub-millimeter telescope mapped the faint light left over from the Big Bang, revealing the earliest structure in the Universe that billions of years later would become the vast clusters of galaxies that astronomers observe today. We now can confirm that the Universe is flat (Euclidean) and that space is accelerating. Capping years of technology development, the long duration ballooning (LDB) capability has been repeatedly demonstrated and is now fully operational. Work is underway to demonstrate an ultra-long duration capability in 2001. Collaboration work with JPL is focusing on ULDB technologies that could be useful for planetary exploration programs on other worlds such as Mars or Venus.

In FY 2000 19 sounding rocket missions were flown, of which 16 were successful flights. The sounding rockets included determination of the ionospheric effects of lightning strokes, the validation of new soft-x-ray measurement techniques and vital SOHO mission support. In FY 2001 expected accomplishments include high-resolution studies of atmospheric gravity waves, calibration of the TIMED satellite by flying under it, and a multi-rocket study of the upper atmosphere enabled by the development of new, small Viper Dart rockets.

BASIS OF FY 2002 FUNDING REQUIREMENT

SPACE SCIENCE INVESTMENTS

	FY 2000	FY 2001	FY 2002
	(Thousands of Dollars)		
Enterprise Contribution to Academic Programs..................	10,200	13,200	
Education Program		1,500	
Minority University Research and Education Program.....	10,200	11,700	
Total	10,200	13,200	

* In FY 2002, Space Science for academic programs is transferred to Academic Programs as an agency-wide consolidation of funding in academic programs. Detailed FY 2002 information can be found in the *Academic Programs* section.

BASIS OF FY 2002 FUNDING REQUIREMENT

SPACE SCIENCE INSTITUTIONAL SUPPORT

	FY 2000	FY 2001	FY 2002
		(Thousands of Dollars)	
Institutional Support to Space Science Enterprise.........................	[330,369]	[303,675]	333,362
Research and Program Management	[310,482]	[282,347]	311,914
Personnel and Related Costs.................................	[238,848]	[227,165]	243,324
Travel	[6,967]	[5,914]	6,331
Research Operations Support................................	[64,667]	[49,268]	62,259
Construction of Facilities	[19,887]	[21,328]	21,448
Full-Time Equivalent (FTE) Workyears	**[2,362]**	**[2,173]**	**2,187**

Note - FY 2000 and FY 2001 data in this section are for comparison purposes only. See *Mission Support* sections for more details.

The Space Science budget contains funding for civil servants at Goddard Space Flight Center, Ames Research Center, Langley Research Center, Marshall Space Flight Center, Johnson Space Center, and Headquarters. Jet Propulsion Laboratory is a Federally Funded Research and Development Center; therefore, the Lab's employees are not civil servants, and their personnel and related costs are included in direct program costs.

Goddard Space Flight Center (GSFC)

The Office of Space Science provides approximately 49% of GSFC's institutional funding. GSFC personnel manage physics and astronomy activities in the following discipline areas: gamma ray astronomy, X-ray astronomy, ultraviolet and optical astronomy, infrared and radio astronomy, particle astrophysics, solar physics, interplanetary physics, planetary magnetospheres, and astrochemistry. GSFC is also responsible for conducting the mission operations for a variety of operating spacecraft. Other activities include managing NASA's sounding rocket and scientific balloon program.

GSFC personnel also conduct planetary exploration research into the physics of interplanetary and planetary space environments, and they participate in planetary mission instrument development, operations, and data analysis. In addition, GSFC FTEs develop technologies targeted at improved spaceborne instruments, and on-board spacecraft systems and subsystems.

Ames Research Center (ARC)

The Office of Space Science provides approximately 13% of ARC's institutional funding. Ames Research Center has the agency lead role in Astrobiology (the study of life in the universe), which focuses on the origin of life and its possible development on other worlds. R&PM funding covers planetary atmosphere modeling, including relationships to the atmosphere of the Earth; research into the formation of stars and planetary systems; and an infrared technology program to investigate the nature and evolution of astronomical systems. Development continues of the Stratospheric Observatory for Infrared Astronomy (SOFIA) for research to be conducted by various NASA/university teams. Research and development in advanced information technologies are directed toward significantly increasing the efficiency of SOFIA as it becomes operational.

Langley Research Center (LaRC)

The Office of Space Science provides approximately 4% of LaRC's institutional funding. Langley Research Center personnel support the solicitation and selection process of the Office of Space Science's (OSS) Discovery, Explorer and Solar Terrestrial Probes Programs. They also conduct reviews of candidate and selected missions and independent assessments of on-going Space Science missions to help ensure that OSS criteria for high quality science return within cost and schedule constraints are met. LaRC technologists will conduct a technology development program that develops advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of space science instruments and systems. Langley is developing the SABER instrument, which is on the TIMED mission to explore the mesosphere and lower thermosphere. Langley scientists are also analyzing SAMPEX data to assess the relative importance of solar terrestrial coupling due to varying electron precipitation compared to that due to 11-year solar flux variations. Langley has provided and continues to provide analysis of spacecraft aerodynamics, aerothermodynamics and flight dynamics for spacecraft entering planetary atmospheres (including Earth) in support of both spacecraft design and flight operations.

Marshall Space Flight Center (MSFC)

The Office of Space Science provides approximately 7% of MSFC's institutional funding. MSFC was the NASA lead center for Chandra X-ray Observatory development and, following Chandra's successful launch and deployment on July 23, 1999, MSFC continues to lead the on-orbit science operations phase. MSFC personnel will also continue leading the Relativity Mission (Gravity Probe-B) and will continue to manage other selected payloads. Leading the Agency in Space Optics Manufacturing and Technology, MSFC technologists will develop ultra lightweight large-aperture optics and optical technology for space applications, provide world class facilities and capabilities for optics fabrication, metrology, and undertake tests that will benefit NASA, other government agencies, academia, and industry.

Johnson Space Center (JSC)

The Office of Space Science provides approximately 2% of JSC's institutional funding. The Johnson Space Center (JSC) scientists support the Agency's planetary science program in the area of geosciences required to support future programs, provide curatorial support for lunar materials, assist in information dissemination, and interact with outside scientists. Their research focuses on the composition, structures, and evolutionary histories of the solid bodies of the universe.

Headquarters (HQ)

The Office of Space Science provides approximately 2% of HQ's institutional funding. The Enterprise's Institutional Support figure includes an allocation for funding Headquarters activities based on the relative distribution of direct FTE's across the agency. A more complete description can be found in the Mission Support/two Appropriation budget section.