U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

HEARING CHARTER

NASA's Space Science Programs:
Fiscal Year 2008 Budget Request and Issues

Wednesday, May 2, 2007
10:00a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose:

On Wednesday, May 2, 2007 at 10:00 am, the House Committee on Science and Technology, Subcommittee on Space and Aeronautics will hold a hearing to examine the National Aeronautics and Space Administration's (NASA) Fiscal Year 2008 budget request and plans for space science programs including heliophysics, planetary science (including astrobiology), and astrophysics, as well as issues related to the programs.

Witnesses:

Witnesses scheduled to testify at the hearing include the following:

Dr. S. Alan Stern
Associate Administrator,
NASA Science Mission Directorate

Dr. Lennard Fisk
Thomas M. Donahue Distinguished University Professor of Space Science
University of Michigan, and
Chair, Space Studies Board, National Research Council

Dr. Garth Illingworth
Professor
University of California Observatories/ Lick Observatory,
University of California, Santa Cruz, and
Chair, Astronomy and Astrophysics Advisory Committee

Dr. Daniel Baker
Professor, Astrophysical and Planetary Sciences
Director,
Laboratory for Atmospheric and Space Physics
University of Colorado, Boulder

Dr. Joseph Burns
Irving Porter Church Professor of Engineering and Professor of Astronomy, and
Vice Provost, Physical Sciences and Engineering
Cornell University

BACKGROUND

Potential Issues

The following are some of the potential issues that might be raised at the hearing:

- ***Impact of Budgetary Cutbacks on NASA's Space Science Programs—****In the three years since the President's Vision for Space Exploration was announced in early 2004, the Administration has reduced NASA's Science Mission Directorate outyear funding by a total of $4 billion. As a result, missions have been delayed or deferred, supporting activities such as technology development have been decreased and the prospects for new activities have been pushed out into the future. At the same time, some missions in development are costing more than anticipated, placing further stress on Science Mission Directorate programs. How serious a problem is the budgetary situation facing NASA's Science Mission Directorate? What should be done to ensure NASA has a sustainable and robust science program?*

- ***Role of Space Science in the President's American Competitiveness Initiative and Innovation Agenda—****Research funded through NASA's space science program exemplifies the types of research highlighted in the National Academies report, Rising Above the Gathering Storm* *and in the President's American Competitiveness Initiative. Specifically, the Academies' recommendations for long-term basic research and "special emphasis on physical sciences, engineering, mathematics, and information sciences"; high-risk research; research grants to early career researchers; and funding for advanced research instrumentation and facilities also apply to NASA. Given that, why hasn't NASA space science been included in the President's American Competitiveness Initiative? Moreover, why has the NASA-funded research that most directly applies to the goals of the ACI been declining at a time when the focus on and funding for long-term basic research at other agencies is increasing under the ACI? What message does the exclusion of NASA research from the ACI send to the community of space scientists that performs that research? How does a strategy that promotes basic research at some government R&D agencies while cutting funding for the same type of research at other agencies help the nation meet the ACI goals of strengthening research in the physical sciences, engineering, and mathematics and building the foundation for innovation? What, if anything, should be done to address NASA's absence from the ACI?*

- ***Lack of Adequate Balance—****Administrator Griffin testified at the March 15, 2007 Committee on Science and Technology hearing on the NASA FY08 budget request that NASA has attempted to balance its science programs. However, a number of advisory committees, including, the National Academies and the Astronomy and Astrophysics Advisory Committee, have raised concerns about the lack of balance in NASA science programs. In its report An Assessment of Balance in NASA's Science Programs (2006), the National Academies found that :*

> *"The program proposed for space and Earth science is not robust; it is not properly balanced to support a healthy mix of small, medium, and large missions and an underlying foundation of scientific research and advanced technology projects."*

According to the Assessment of Balance report, lack of balance, sustainability and robustness in NASA's science programs affects the ability to make progress on the Decadal Surveys (research priorities *for the next ten years in specific space science disciplines that represent a consensus of the science community); to follow a plan or sequence of missions, to meet commitments to international partners; to develop advanced technology; to nurture a research and technology community; and to train and educate future space scientists and engineers. What is NASA's definition of balance? What, if anything has NASA done in response to findings of the advisory committees? What does a properly balanced program look like?*

- ***Cuts to smaller science mission opportunities—****Cutbacks in small- and medium-sized mission opportunities, such as are offered by the Explorer program, are cited in advisory committee reports as indicators of a science program lacking balance. Explorer missions, which are highly rated in the decadal surveys, are competitively awarded missions that are led by a scientist principal investigator (PI) who is given responsibility for the scientific, technical, and management success of the mission. Explorers examine focused science areas not addressed by NASA's larger, agency-led, strategic missions. They provide flight opportunities in the gaps between strategic missions and are critical opportunities for the much-needed training of the next generation of scientists and engineers. That the Nobel Prize in physics for 2006 was awarded to two U.S. researchers whose work relied on data from the Cosmic Background Explorer (COBE) exemplifies the scientific potential of these small spacecraft. Should funds be restored to increase the flight rate of Explorer and other small- and medium-sized missions, and at what cost to other missions or science activities? What is the appropriate frequency of small- and medium-sized missions needed to sustain the scientific activities and researcher base that relies on such flight opportunities? Should future budgets fence off a certain percentage of resources for small- and medium-sized missions such as Explorer?*

- ***Cuts to Research and Analysis—****According to advisory committee reports such as <u>An Assessment of Balance in NASA's Science Programs</u> and the <u>Annual Report of the Astronomy and Astrophysics Advisory Committee, March 16, 2006- March 15, 2007</u>, a properly balanced science program is defined, in part, by the support provided for research grants, largely through NASA's research and analysis (R&A) accounts. R&A grants fund theory, modeling, and the analysis* *of mission data; technology development for future science missions; the development of concepts for potential future science missions; scientific investigations using aircraft, balloons, and suborbital rockets; the training of the next generation of scientists and engineers, among a host of other supporting research and technology activities. The FY06 NASA operating plan cut R&A accounts by about 15% across the science programs, reducing support for graduate students, post-doctoral students and junior faculty. The FY07 request did not restore those cuts, and the FY08 request largely continues the previous levels of funding for R&A. What is a healthy level of R&A funding within the NASA science programs? How long can the research community sustain lower levels of activity before attrition occurs, along with a loss of expertise that cannot be easily recovered? What, if anything, should be done about the current level of R&A funding? Should measures be instituted to protect R&A funding against future cuts, and if so, what would those measures be?*

- ***Cost Growth in Missions—****Several of the increases in NASA's FY08 budget request provide funds for science missions that have run over budget or schedule, or that run the risk of doing so. In addition, cost growth in some of the planned space science missions in recent years, coupled with constrained budgets, has wound up squeezing other science activities. The factors contributing to cost and schedule growth are not easy to pinpoint, but can include underestimates in the technology development required for mission readiness; increases in launch vehicle costs; internal decisions to delay missions or alter budget profiles; project management difficulties; and delays in contributions from international or interagency partners. Lack of clarity in the communication of what is included in those costs (e.g., technology development, mission development, operations) has also contributed to the problem. Mission cost growth can lead to delays, cancellations, or reduction in funds for other NASA science missions and activities. What, if anything, can be done to control cost growth on missions? Is there adequate understanding of the cost growth contributors or is more information needed to come up with solutions to the cost growth problem?*

- ***Role of Space Science in Human and Robotic Exploration of the Solar System—****Robotic exploration of the solar system is called out in the President's Vision for Space Exploration as being important to* *achieving the Vision. The Report of the President's Commission on Implementation of United States Space Exploration Policy states that "science in the space exploration vision is both enabling and enabled." What should be the role of science activities in the context of the Vision for Space Exploration? Should science that supports the Vision have a higher priority?*

- ***Future Availability of the Delta II Launch Vehicle—****The Delta II has been a highly reliable workhorse for space science missions. Over the next two years, 8 missions are scheduled to launch on Delta IIs, however, NASA has expressed uncertainty about the availability of the Delta II launch vehicle after 2009 and is studying alternatives. What is the status of the Delta II availability for science payloads after 2009? If the Delta II is not available, what is the plan for launching Delta-class science missions? What are the alternatives to the Delta II and what are the likely impacts of using an alternative vehicle? If launch costs increase, does NASA plan to alter the levels of cost-capped missions?*

- ***Technology Development and Supporting Programs—****missions proposed with immature technologies can be a root cause of cost growth. The Academies report on Principal-Investigator-Led Missions in the Space Sciences states that "…project technology development efforts often lag planned progress owing to unexpected design failures, fabrication or testing issues, or other glitches. … attempts by mission projects to using promising but immature technology is a frequent cause of PI-led missions (and others) exceeding the cost cap." The FY08 budget request decreases funding for the New Millennium Program and the research and analysis programs both of which enable technology development for future missions. In light of the cost growth and technical challenges encountered by several science missions, will reductions in technology development programs increase the risk of cost growth on future missions? Have technology development programs been an adequate and effective means of understanding technical risks and mission costs? If not, why and what other mechanisms are available to prepare for technical challenges on future missions?*

- ***International Partnerships—****NASA has a successful history of international cooperation in science and involves non-U.S. partners* *on some two-thirds of its science missions, and also provides instruments, science support, and other in-kind contributions to non-U.S.-led space and Earth science missions. Successful cooperative missions can increase the scientific content of a mission and build mutually beneficial relationships. At the same time, cooperation can lead to delays and added mission costs. Among the factors that have made international cooperative missions harder in recent years is ITAR. Pursuant to 22 U.S.C. 2778 of the Arms Export Control Act, the International Traffic in Arms Regulations (ITAR) regulates the export of defense articles on the U.S. Munitions Control List. The Department of State has responsibility for administering the regulations. In 1999, scientific satellites were added to the Munitions Control List (USML). ITAR often poses significant challenges for space science missions, many of which involve international partners. The time required to manage licenses or agreements can threaten mission schedules. ITAR can be especially problematic for U.S. universities, which typically attract a large percentage of foreign graduate students to their programs. Is increasing international cooperation on planned and future missions feasible, given recent experiences with ITAR? What factors associated with ITAR must be considered before agreeing to international collaborations?*

Overview

Over the past five decades, NASA has fostered a world-class space science program that has led to such discoveries as new planets outside our solar system, the presence of dark energy and the acceleration of an expanding Universe, the signs of possible recent liquid water flows on Mars, and more knowledge of the Sun's interior structure and activity. NASA missions have also improved our understanding of the effects of solar activity and space radiation on ground-based electrical power grids and wireless communications systems, on orbiting satellites, and also on humans in space. The space science program's technical achievements are equally stunning as demonstrated in the successful landing and operation of Mars rovers Spirit and Opportunity; the recent deployment of five spacecraft to study the causes of the changing auroras at the North Pole, and Deep Impact's successful penetration of the comet Tempel 1. In 2006, Dr. John Mather and Dr. George Smoot were awarded the Nobel Prize in physics for their work with the NASA Cosmic Background Explorer. [Dr. Mather is the first NASA civil servant to receive the Nobel prize.]

This hearing will examine NASA's space science programs within NASA's Science Mission Directorate (SMD) and their status within the context of the Fiscal Year 2008 budget request. The space science programs include the following theme areas:

- Heliophysics, which seeks to understand the Sun and its effects on Earth and the rest of the solar system;
- Planetary science, which seeks to understand the origin and evolution of the solar system and the prospects for life beyond Earth; and
- Astrophysics, which seeks to understand the origin, structure, evolution and future of the Universe and to search for Earth-like planets.

Earth science is also an SMD theme area. It will be the topic of a separate subcommittee hearing.

It should also be noted that Dr. Stern has informed the subcommittee that he has gotten agreement to move NASA's Near Earth Objects (NEO) program, and its associated budget, from the Exploration Systems Mission Directorate to the Science Mission Directorate.

NASA's space science programs involve the following types of activities:

- space missions that take measurements and collect data to investigate high priority science questions;
- the analysis of that mission data, which leads to new knowledge;
- research on theories and models;
- the development of new technologies to enable future science investigations; and
- the use of balloons, sounding rockets, and suborbital flights to take measurements and test technologies.

Stakeholders in the NASA space science programs include academic institutions; industry; NASA field centers, predominantly the Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory (JPL); and other government laboratories. There are a number of advisory panels that provided guidance on NASA's space science programs and activities, including the NASA Advisory Council (NAC) and the NAC Science Subcommittees, the National Academies, and the Astronomy and Astrophysics Advisory Committee (AAAC).

Fiscal Year 2008 Budget Request

The President's FY08 budget requests $4.019 billion to fund NASA's space science programs—heliophysics, planetary science, and astrophysics. The budget represents a $16.5 million increase (or about 0.4%) over the President's proposed FY07 budget. (Appendix A presents the President's FY08 budget request for NASA space science programs.) Space science programs represent 23.2 percent of the President's total FY08 budget request for NASA. Within the proposed FY08 budget for space sciences programs, heliophysics represents 26 percent, planetary science represents 35 percent and astrophysics represents 39 percent of the total space science funding.

Comparing the President's FY08 budget request with the funding requested for FY08-FY11 in the President's FY07 proposal (and under full cost simplification) shows that planetary science gains $87M, while heliophysics loses over $300M and astrophysics is decreased by about $125M. The FY08 budget request shows the following cumulative results for individual science missions, over the FY08-FY11 period, relative to the President's FY07 budget request:

- NASA adds funding to support the development of several key missions and mission areas, including (in millions of dollars):

James Webb Space Telescope	+ 95.6
Stratospheric Observatory for Infrared Astronomy	+344.9
Hubble Space Telescope	+ 3.5
Gamma Ray Large Area Space Telescope	+ 17.0
Kepler	+ 53.2
Astrophysics research missions (in operation)	+134.9
Planetary science research	+378.8

- However, there are significant funding cuts to other space science activities, activities over the same period, such as (in millions of dollars):

Navigator (missions on extrasolar planets)	-819.6
Mars missions/ exploration	-264.7
New Millennium (tech validation missions)	-124.5
Solar Terrestrial Probes (heliophysics mission)	- 84.6
Living with a Star (space weather missions)	- 83.5
Discovery cost-capped planetary program	- 51.6
Beyond Einstein program	-33.9
Heliophysics research	-13.6

In 2008, the Science Mission Directorate plans to launch Kepler, Interstellar Boundary Explorer, Solar Dynamics Observatory, conduct a fourth Hubble servicing mission; and complete contributions to international and interagency partner missions that are planned for launch in 2008.

Heliophysics

The President's FY08 budget request for NASA includes $1.057 billion for the Heliophysics theme, which seeks to understand the Sun and its effect on the Earth, the rest of the solar system, and the conditions in the space environment and their effects on astronauts; and to develop and demonstrate technologies to predict space weather.

Programs within the Heliophysics theme include:

- *Heliophysics Research*—research and analysis; space missions; sounding rockets and other scientific platforms; science data and computing technology;

- *Living with a Star*—investigations to understand solar variability (space weather), its effect on the Earth and the rest of the solar system, and the implications for ground-based systems such as electric power grids and wireless communications, and for on-orbit spacecraft and astronauts. Space missions under the Living with a Star program include:

    - Solar Dynamics Observatory (SDO) to understand the structure of the Sun's magnetic field and how magnetic field energy forms the solar wind, energetic particles, and fluctuations in solar irradiance. SDO will help acquire data to enable space weather predictions. SDO is slated to launch in 2008.

  - Radiation Belt Storm Probes (RBSP) to investigate solar storms and their interaction with charged particles, fields, and radiation in the Van Allen radiation belts. The results of the mission will be used to develop models that assist engineers in designing systems to withstand radiation effects and to alert pilots and crews of potentially hazardous solar storms or radiation. RBSP is estimated to launch around 2012.

- *Solar Terrestrial Probes*—missions to investigate the Sun, the heliosphere, and planetary environments as an interrelated system. Missions within the Solar Terrestrial Probe program include:

  - Magnetospheric Multiscale (MMS) is proposed as a system of four spacecraft to investigate processes such as magnetic reconnection, which involves the transfer of energy from the solar wind to the Earth's magnetosphere, and is an important factor in predicting space weather. The estimated launch date for MMS is 2013.

- *Heliophysics Explorer Program*—small and medium-class competitively-selected missions that endeavor to provide frequent flight opportunities to investigate focused research. Explorer programs are cost-capped and awarded to individual principal investigators who have sole responsibility for the scientific and technical success of the mission.

- *New Millennium*—a program to validate technologies for use in future space science missions. The program reduces the risk of new technologies that have not yet been flown in space.

- *Deep Space Mission Systems*—telecommunications and navigation services (e.g., the Deep Space Network) to support human and robotic exploration of the solar system. [This program is located in Heliophysics as a bookkeeping function in the FY08 request.]

Issues

- *"Flagship" missions including the James Webb Space Telescope, which is under development in the Astrophysics Program, and the Cassini mission which is currently investigating Saturn, for the Planetary Science program, represent long-term, high priority scientific investigations for those disciplines. The National Academies decadal survey for solar and space physics recommended in 2003 the Solar Probe as a flagship mission to measure the heating and acceleration of the solar wind. According to NASA's Science Plan for 2007-2016, "a flagship mission cannot be supported within the available funding resources." What are NASA's plans for Solar Probe and why are flagship missions being pursued in other science disciplines but not in Heliophysics? How does the absence of a Solar Probe mission affect the balance of the Heliophysics program?*

Planetary Science

The President's FY08 budget request provides $1.396 billion to fund NASA's Planetary Science theme, which seeks to understand:

- the history and evolution of the solar system;
- whether life existed or exists beyond Earth

The FY08 budget represents a decrease of $15.4 million or 1 percent cut relative to the President's FY07 budget request for planetary science.

The Planetary Science program includes the following elements:

- *Mars Exploration*—several mission projects aimed at exploring Mars for indicators of life, helping to understand the history of the solar system, and to improving our understanding of the potential hazards to humans in future Mars explorations.
    - Mars Scout 2007 (Phoenix) is a mission to help understand the chemistry, mineralogy and composition of gases in surface and subsurface soils at areas in the northern latitudes of Mars. The Mars Scout line is led by a principal investigator, a scientist who is selected competitively to lead the development of a

mission and ensure its scientific and technical success. Mars Scout missions are cost-capped at $475M (FY06 dollars). Phoenix is scheduled for launch in August, 2007.

  - Mars Science Laboratory is a NASA strategic rover mission designed with a new entry, descent and landing system to take measurements focused on identifying possible Martian habitats for life. Mars Science Laboratory is scheduled for launch in 2009.

- *Discovery Program*—a program of missions that offer scientists opportunities to form a team and submit a proposal to design and develop innovative, medium-sized, missions that address focused science objectives. Proposals are competed; NASA awards funds to the scientist, as principal investigator, leading the selected proposal. Principal investigators are responsible for the scientific, technical and managerial success of the mission. Discovery missions are cost-capped at $425M, according to the Announcement of Opportunity issued in 2006. Discovery missions under development include Dawn—a mission whose purpose is to visit and study Vesta and Ceres, the two largest asteroids in the solar system. Dawn is scheduled for launch in June 2007.

- *New Frontiers*—offers opportunities for scientists to form a team and propose to design and develop innovative, medium-sized missions that focus on understanding the origin, evolution, and formation of the solar system. New Frontiers missions are led by principal investigators and have a cost-cap up to $700M in FY03 dollars, as of 2006. New Frontiers missions include:

  - New Horizons, launched in 2006, which is en route to Pluto where it will collect data about the geology and atmosphere of Pluto and its moon, Charon.

  - Juno, a mission that is being planned to investigate several aspects of Jupiter including its interior structure and its atmosphere. Juno is being planned for launch in 2011. Juno is a high priority mission of both the National Academies' solar system exploration and solar and space physics decadal surveys.

- *Technology*—a program to develop Radioisotope Power Systems such as radioisotopic thermoelectric generators and In-Space Propulsion technologies such as solar electric propulsion and solar sail propulsion that enable solar system exploration missions to reach distant outer planets at lower costs, with less mass, and for shorter travel times.

- *Planetary Science Research* includes research and analysis, lunar science and funding for existing missions and planetary data archiving. Specific program elements include:

  - Research and Analysis programs involve the development of theory and instrumentation to enable future planetary science missions as well as research on specific interdisciplinary areas such as astrobiology and cosmochemistry (research on the origins and evolution of planetary systems and for study of the atmospheres, geology, and chemistry of planets in the solar system).

  - Lunar Science is a new program in the FY08 request, which provides funds for the archiving of lunar science data, lunar science instruments and payloads that are selected through peer review, analysis of data from lunar missions, and technology development for lunar science missions.

  The planetary science research program also supports planetary data systems and astromaterials curation; the Cassini Huygens mission; U.S. involvement in non-U.S. missions such as the European cometary mission, Rosetta, and the Japanese cometary sample return mission, Hayabusa.

Issues

- *NASA created the interdisciplinary field of astrobiology in the late 1990s to increase knowledge on the origin and evolution of life on Earth and beyond Earth. Two National Academies decadal surveys strongly support Astrobiology, and Astrobiology contributes to NASA's own strategic goal to "Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere,* *and the hazards and resources present as humans explore space," as stated in the 2006 NASA Strategic Plan. According to the January – March 2007 Newsletter of the National Academies' Space Studies Board, over the last two years, NASA cut the budget for Astrobiology by 50%, from approximately $65 million to $31 million. In FY07, reductions in the astrobiology budget reduced the number of research institutions participating as part of the NASA Astrobiology Institute from 16 to 12, and the funding for those 12 teams was reduced. [The Astrobiology Institute is a consortium of institutions that have been competitively selected and provided seed funding for astrobiology research programs.] No new research has been provided in the Astrobiology Science and Technology for Exploring Planets program or the Astrobiology Science and Technology Instrument Development program since 2004. Funding for grants in the exobiology and evolutionary biology program has been delayed. The cuts to the research program have affected graduate students, post-doctoral students and junior faculty, who rely on grant funding for their research. The decrease in available funding and research opportunities is expected to discourage younger scientists from entering the field.*

- *The FY08 budget request adds $27 million of new content in FY08 through the creation of a lunar science research program in the Planetary Science Research line. The total funding budgeted for lunar science through FY2012 is $350 million. The goals for the lunar science program over the next five years include archiving of data from the lunar precursor robotics missions; launching missions of opportunity for scientific instruments on lunar precursor robotic missions or international lunar missions and funding the analysis of data from those missions. Plans for the lunar science program also involve providing opportunities for developing instruments and technologies to support lunar science studies and investigations. What priority will the new lunar science program have relative to other space science research activities? Is it intended to support the human lunar exploration program, or is it independent of that initiative?*

Astrophysics

The President's NASA FY08 budget request includes $1.566 billion to fund NASA's Astrophysics program, which seeks to improve our understanding of the origin, structure, evolution and future of the Universe and to search for Earth-like planets. The FY08 request represents a $2.8 million or .02% increase over the President's FY07 budget proposal.

The Astrophysics program includes the following elements:

- *Astrophysics Research* includes managing operating missions; managing, archiving, and disseminating mission data; funding science research and data analysis; and technology development

- *Gamma-ray Large Space Telescope (GLAST)* is a mission being conducted with NASA and the Department of Energy. The mission will take measurements of high-energy gamma rays in an effort to understand their sources and behavior. GLAST is scheduled for launch in November 2007.

- *Kepler* is a competitively-selected principal investigator-led mission in the Discovery program that will search for Earth-like planets. Kepler is scheduled for launch in November 2008.

- *James Webb Space Telescope* (JWST) is an infrared observatory involving a 6.5m aperture mirror and sunshade that will unfold upon deployment in space. JWST will enable scientific study of the early Universe and of the development of galaxies, stars, planetary systems and the elements required for life. JWST is the top-ranked mission from the last National Academies decadal survey in astronomy and astrophysics and is considered the successor to the Hubble Space Telescope. JWST is slated for launch in 2013.

- *Hubble Space Telescope* is a space observatory currently utilized to study and understand the formation, structure, and evolution of stars and galaxies in the visible, near infrared and ultraviolet wavelengths. The Hubble was designed to be serviced from space. The fourth Shuttle servicing mission is scheduled for September 2008 to replace batteries, gyroscopes, and other systems necessary for operating capabilities and to add new scientific instruments. Hubble was launched in 1990.

- *Navigator Program* involves several projects aimed at the search for habitable planets beyond the solar system:

    - Space Interferometer-PlanetQuest (SIM) is a mission to conduct a census of planetary systems and to identify the location and masses of targets for potential further study. SIM is a technology development project.

    - Terrestrial Planet Finder (TPF) is a concept for a space mission that would detect planets similar to Earth in the areas of nearby stars that are considered possible for the formation of Earth-like planets. TPF would collect and analyze data on the spectra of planets it identified for possible signs of life. TPF is a technology development project.

    - The Keck Interferometer (KI) is a ground-based effort currently under development to measure the dust and gas around stars, especially the inner region of stars where Earth-like planets may form.

    - Large Binocular Telescope Interferometer (LBTI) in under development and will take measurements of the dust and gas surrounding stars, including the outer ranges of disks around stars where it is thought that Jupiter-like planets might form and evolve.

- *Stratospheric Observatory for Infrared Astronomy (SOFIA)* is an astronomical observatory to help understand the birth and death of stars, how new solar systems form, among other astrophysical questions. The SOFIA observatory includes a 2.5 meter telescope, provided by the German Aerospace Center (DLR), that will be mounted on a customized Boeing 747 aircraft.

- *Astrophysics Explorer Program* provides opportunities for researchers to assemble a team and propose to design and develop a focused science mission. Explorer missions are led by principal investigators and are cost-capped. The program is intended to offer frequent flight opportunities and to conduct focused science investigations that complement larger, NASA-developed strategic missions. Astrophysics Explorer missions in development include Wide-Field Infrared Survey Explorer (WISE) which seeks, as a main objective, to find the brightest galaxies in the Universe. WISE is slated for launch in 2009.

- *International Space Science Collaboration*, which involves the U.S. contribution of instruments, subsystems, and U.S. investigators to two European-led missions.

- *Beyond Einstein*, a program including space missions, research and theory work, and technology development aimed at improving our understanding of proposed missions to help understand Einstein's theory of general relativity and its predictions about the Big Bang, black holes, and dark energy. NASA has commissioned a National Academies study to recommend which Beyond Einstein mission should be developed and launched first. The Beyond Einstein program, as described in NASA's FY08 budget request documentation, includes:

    - Laser Interferometer Space Antenna (LISA), a collaborative mission with the European Space Agency to measure gravitational waves.

    - Constellation-X Observatory (Con-X), a mission that will harness the collective power of several x-ray telescopes to investigate black holes, Einstein's theory of general relativity, the formation of galaxies, and the nature of dark matter and dark energy, among other science goals.

    - Joint Dark Energy Mission, which will study the nature of dark energy in the Universe and the expansion of the Universe.

    - Beyond Einstein Future Missions, which include an Inflation Probe to study the causes of the inflation of the Universe and Black Hole Finder Probe, which will conduct a census of black holes to identify where they are and when and how they form.

Issues

- *The Navigator Program, a project within the Astrophysics theme, seeks to understand how planets and planetary systems form, search for planets around other stars, and characterize those planets and their environments for signs of potential life. The Space Interferometer-PlanetQuest (SIM) mission along with the Terrestrial Planet Finder (TPF) mission are integral components of the Navigator Program. The 2001 astronomy and astrophysics decadal survey recommends SIM for completion and TPF as a technology development project. The President's FY07 request for NASA delayed SIM to a potential 2015 or 2016 launch and deferred TPF development indefinitely. The FY08 request cuts $800M from the Navigator Program between FY08 and FY11. The FY08 request does provide funds ($35.5M) for reinstating technology development work on TPF. What is the appropriate path for the Navigator program? Should funding be restored to put SIM back on track for mission development? Should funding for TPF technology development be increased? Should both the SIM and TPF missions be deferred until they can be reconsidered in the next decadal survey?*

- *As can be seen in the chart below, a large number of highly recommended astrophysics missions have been delayed, cancelled, or deferred. At the same time, the recent National Academies Assessment of NASA's Astrophysics Program noted that: "Although six astrophysics Explorer missions have been launched in the current decade, those launches are the result of development work performed mostly in the 1990s. At this point it appears that only one Explorer mission will be developed and launched in this decade, and at most one Explorer will begin development in this decade for launch in the next." What is the outlook for the Astrophysics program if current trends continue, and what should be done?*

Summary of NASA Plans for Recommended Large and Moderate Astrophysics Missions

MISSION	Recommended by	Launch Date 2003 Plan	2006 Plan	Status
Hubble Space Telescope Servicing Mission-4	1980s, 1990s, 2001 decadal surveys	2004	2008	DELAY
Space Infrared Teles. Facility (SIRTF)	1990s, 2001 surveys	2003	2003	LAUNCHED
Stratospheric Observatory for Infrared Astronomy (SOPHIA)	1990s, 2001 surveys	2005	Canceled	REINSTATED
Space Interferometry Mission (SIM)	1980s, 1990s, & 2001 surveys	2005-2010	NET 2015	DELAY
Keck Telescope Outriggers		2003	Canceled	Canceled
Herschel/ Planck	European Space Agency	2007	2008	DELAY
Gamma-ray Large Area Space Telescope (GLAST)	2001 survey	2007	2007	
Kepler (Discovery)	2001 survey	2007	2008	DELAY
James Webb Space Telescope	2001 survey	2005-2010	2013	DELAY
Constellation-X	2001 survey, Q2C	NET 2011	NET 2016	DELAY
Terrestrial Planet Finder	2001 survey	2010-15	NET 2018	DELAY
Laser Interferometer Space Antenna	2001 survey, Q2C	NET 2011	NET 2016	DELAY

Summary of NASA Plans for Recommended Large and Moderate Astrophysics Missions

MISSION	Recommended by	Launch Date 2003 Plan	2006 Plan	Status
Black Hole Finder Probe	2001 survey	NET 2012	Deferred	DEFERRED
Single Aperture Far Infra-Red Observatory	2001 survey, Q2C	Deferred	Deferred	DEFERRED
Inflation Probe	Q2C	NET 2012	Deferred	DEFERRED
Joint Dark Energy Mission	Q2C	NET 2012	Deferred	DEFERRED
Large Binocular Telescope Interferometer	2001 survey	2005	2009	DELAYED

Source: Modified from National Research Council, *A Performance Assessment of NASA's Astrophysics Program,* National Academies Press, Washington, D.C., 2007.

Note: Q2C is an abbreviation for National Research Council, *Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century*, National Academies Press, Washington, D.C., 2003.

- *The President's FY08 budget request includes an estimate for a Space Shuttle servicing mission of the Hubble Space Telescope in May 2008, and the budget proposes funding to support that date. An updated Shuttle manifest moved the mission to September 2008, leaving a gap of 4 months or $40 million ($10 million a month in costs). The current tentative Shuttle manifest has moved the* *mission forward to an August 2008 launch, although further changes and launch delays could widen the funding shortfall. It is not yet clear where NASA will find the $40 million to fill the gap.*

APPENDIX A **FY 08 NASA Budget Request**

(Budget authority, $ in millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
SCIENCE	**4,002.3**	**4,018.8**	**4,009.5**	**4,080.5**	**4,245.7**	**4,449.5**
PLANETARY SCIENCE	**1,411.2**	**1,395.8**	**1,676.9**	**1,720.3**	**1,738.3**	**1,748.2**
Discovery	179.9	184.9	320.7	370.2	355.2	341.1
New Frontiers	158.1	147.3	296.0	277.5	267.9	274.5
Solar System Technology	73.4	67.6	62.6	63.9	62.7	64.2
Planetary Science Research	278.8	370.5	402.9	416.2	428.5	402.9
Mars Exploration	721.1	625.7	594.8	592.5	624.0	665.5
HELIOPHYSICS	**1,028.1**	**1,057.2**	**1,028.4**	**1,091.3**	**1,241.2**	**1,307.5**
Heliophysics Research	221.2	206.1	188.0	201.5	192.8	207.5
New Millennium	89.6	66.2	33.0	36.0	92.1	95.9
Near Earth Networks	63.7	66.0	65.2	67.2	65.6	66.9
Deep Space Mission Systems	254.2	263.0	272.1	277.7	276.5	282.4
Living with a Star	232.5	253.0	269.2	261.4	266.1	286.7
Solar Terrestrial Probes	88.7	126.8	125.3	114.4	181.3	181.5
Heliophysics Explorer Program	78.3	76.1	75.6	133.1	166.8	186.5
ASTROPHYSICS	**1,563.0**	**1,565.8**	**1,304.2**	**1,268.9**	**1,266.2**	**1,393.8**
Navigator	124.7	57.1	58.4	59.5	61.0	62.5
James Webb Space Telescope	468.5	545.4	452.1	376.9	321.1	285.9
Hubble Space Telescope	343.0	277.7	165.2	152.8	151.4	151.3
Stratospheric Obserbatory for Infared Astronomy		77.3	89.1	88.6	89.9	92.1
Gamma-ray Large Space Telescope	90.7	42.2	28.3	28.3	29.3	30.2
Discovery (Kepler)	105.0	93.0	25.7	16.3	16.2	17.6
Astrophysics Explorer	69.4	99.1	88.8	28.2	11.7	5.7
Astrophysics Research	319.8	315.2	306.1	331.9	378.5	491.4
International Space Science Collaboration	19.8	26.5	39.1	38.7	36.5	35.2
Beyond Einstein	22.1	32.3	51.5	147.6	170.6	222.1
Year to Year Increase		**0.4%**	**-0.2%**	**1.8%**	**4.0%**	**4.8%**