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SPACE STUDIES BOARD BULLETIN

FROM THE CHAIR

There can be no more important subject for this quarter's column than the FY2007 budget request for NASA. From my experience, I cannot recall a budget request that has resulted in more consternation and outcry from the science community than this one.

The consternation results in part from a confrontation with reality. The science budget of NASA has grown more rapidly than the agency's budget as a whole since the mid-1990s. This is unsustainable. However, what is a surprise and a disappointment is how abrupt and draconian has been the downward adjustment to science. The budget for the Science Mission Directorate (SMD) is to experience a growth in FY2007 of 1.5% compared to the agency's overall budget growth of 3.2%. SMD's projected budget is to grow only at 1% per year for the next four years, compared with the total NASA budget rising at roughly 2-3%. These figures are much lower than what had been projected in last year's budget. The result is to remove $3.1 billion from the runout of the SMD budget. The projected growth in SMD was not a funding wedge for programs yet to be determined, but rather real programs, supporting the careers and aspirations of real scientists and engineers. One cannot remove $3.1 billion of content without major disruptions. The disruptions are proportionally larger in the life and microgravity sciences programs, which are funded through the Exploration Systems Mission Directorate, and which are to experience a near 70% reduction in content.

In fairness to NASA, there are no good choices for cuts in the FY2007 budget. The agency does not have sufficient funds to pursue its many missions, and it is a question only of whom to disappoint. The agency's bottom-line funding is inadequate. Most space experts considered it inadequate when the President directed NASA in 2004 to pursue an aggressive program of returning humans to the Moon and going on to Mars—the Vision for Space Exploration—while still maintaining its near-term commitments to complete the International Space Station (ISS) and maintain a vigorous science and aeronautics program. It became more inadequate when the Administration did not request the budget for NASA that it projected at the time of that announcement. It became still more inadequate when the costs for flying the Shuttle to complete the ISS proved to be understated. The choices then were to disappoint the international partners on the ISS program by reneging on our commitments to complete the ISS, or disappoint the scientific community by removing the planned growth in its budget in order to fund the completion of the ISS. Or NASA could delay the development of the Crew Exploration Vehicle (CEV) destined to replace the Shuttle, resulting in a longer gap in the United States' ability to launch humans into space, with the corollary consequences for the NASA and industrial workforce that needs to retain the knowledge acquired over decades of how to build and operate human spaceflight systems. Or NASA could disappoint the life and microgravity scientists by taking their funding to develop the CEV. In an overall agency budget that is this constrained, there are no good choices.

Budget reductions are not abstract concepts. They result in individuals being fired and career aspirations being disrupted. The choices that NASA has made for reductions in the planned growth of SMD have the unfortunate consequence of negatively impacting

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a large number of space and Earth scientists, and graduate students who aspire to join their ranks. The small flight missions of NASA, e.g., the Explorers and Earth System Science Pathfinders, were reduced in the FY2005 budget, at the time of the announcement of the Vision for Space Exploration. They are reduced further in the FY2007 budget request, and a new target for reductions is found—the basic grants program in Research & Analysis (R&A)—which is the lifeblood of the space and Earth science communities. The R&A program is to be reduced 15%, retroactively to FY2006, with selected programs such as astrobiology reduced by 50%. It would be difficult to find reductions that impact more space scientists, particularly those in the university community. The outcry that has resulted was predictable.

There is a well-established pipeline for human capital and technology in the space and Earth sciences that runs through R&A and small flight missions. R&A supports the training of graduate students, young investigators, the analysis and interpretation of data from ongoing missions, theoretical studies, the planning for future missions, and the development of new technology prior to its use in flight hardware. The cuts in R&A, beginning in FY2006 and then in subsequent years, disrupt this pipeline, in some fields irrevocably. More than that, the cuts send a chilling message of uncertainty to the young about the opportunities and the promise of the future.

Large technology corporations have long recognized that their cumbersome bureaucracies do not promote innovation. The best of the large technology corporations form alliances with small businesses, which retain the agility and the drive for innovation. The partnerships can be highly effective, with the small business innovating and the large corporation turning the innovation into effective products. Why has this lesson been lost on NASA, or for that matter the Federal government? Universities are the small-business equivalents for the space and Earth sciences. They have highly innovative researchers; they retain their agility. The innovative role of universities has been a central, driving feature of the space and Earth sciences since the inception of the space age. Yet so many recent actions by NASA have driven the university community out of participation in the development of technology for space. NASA is justifiably proud of the fact that its flagship missions support research at universities. This, however, is data analysis and theory. It is not technology development. It is shortsighted and counter to successful corporate strategies for NASA not to avail itself of the technology innovation available in universities through vigorously funded, small missions and R&A programs.

The funding reductions in small missions and R&A have caused disproportional damage to the space and Earth science communities. The converse is also true. Fixing these reductions and ameliorating the damage requires relatively little funding. A 1% change to the overall NASA budget, ~$160 million, applied to the R&A and small missions programs of SMD, and allowing SMD to increase in proportion to the agency's overall budget in the out-years, would go a long way to restoring the pipeline of human capital and technology essential for the future.

The funding reductions in life and microgravity sciences are more drastic and more difficult to restore. Every statement made about the consequences of the reductions in R&A and small missions in SMD is amplified for the life and microgravity sciences. By NASA's own count, the reductions in the grants program in these fields have resulted in laying off more than 500 postdoctoral fellows and graduate and undergraduate students. That is a whole generation of scientists whose expertise is needed to lay down the foundation of knowledge required for NASA's success in implementing the President's Vision.

The FY2007 budget request for NASA has been proposed by the President, and now is in the hands of the Congress. It is to be hoped, even within the constraints now present on the Federal budget, that it will be possible to provide NASA with the funding that is required to accomplish its many missions of national importance. And that it will be possible to undo the disproportional damage that has been done to those programs that are fundamental to our future in space.

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DIRECTOR'S COLUMN

My first four weeks as Director of the Space Studies Board have been action-packed and fascinating. After retiring from the Congressional Research Service on February 28, I joined the SSB as Joe Alexander's successor on March 1. Joe continues to be a member of the SSB staff, working half time (theoretically!) as a study director. My move to the SSB came after 31 years of service in the government, 30 of them at CRS and one as Executive Director of the National Commission on Space (the "Paine Commission") while on a leave of absence from CRS in 1985-1986.

I've joined the SSB during troubling times for the space science community—the broad set of scientists, engineers, educators, and policy-makers involved in space science, Earth science, and life and microgravity sciences. After many years of robust budget growth in many of these areas, NASA Administrator Mike Griffin has pointed out repeatedly since his nomination hearing on April 12, 2005, that NASA cannot afford all of the programs on its plate. Consequently, NASA's science programs are being cut, either in actual terms or in terms of previously projected growth.

Many factors led, almost inevitably, to the current budget situation at NASA. Len Fisk describes many of them in his preceding column. Perhaps the one most often overlooked is the pressure on NASA's top-line budget. Funding requirements to support the war in Iraq and recovery from Hurricane Katrina, coupled with efforts to reduce the deficit, have sharply affected virtually all domestic discretionary programs, including NASA. Many were skeptical about NASA's ability to absorb the costs of the Vision for Space Exploration when it was announced in January 2004, and except for the initial fiscal year (FY2005), the

Bush Administration has not requested the level of promised increases to implement the early stages of the Vision. With internal factors impacting NASA's allocation of its funding resources—compensating for previously understated shuttle budget requirements for FY2008-2010, cost growth in several science programs, and requirements to fund congressionally-directed items—the budget situation at NASA has grown increasingly constrained since the Vision was announced.

As Len emphasizes in his column, it is the abrupt change in direction of science funding that is a major factor in the protests from the science community. Many space scientists had worried that precisely this fate would befall their programs when President Bush announced the Vision. But assurances from former NASA Administrator Sean O'Keefe that most science disciplines were included in the Vision, and later assurances from Dr. Griffin that "not one thin dime" would be taken from science programs to pay for NASA's human spaceflight activities, had assuaged those fears. In announcing the FY2007 budget, with its proposed cuts to the projected growth in science funding, Dr. Griffin expressed his regret that he was not able to fulfill that pledge.

But Dr. Griffin points out that NASA's overall budget ($16.8 billion requested for FY2007, a 3.2% increase over FY2006) and the budget for space and Earth sciences ($5.3 billion in FY2007, a 1.5% increase) are good news in these budget-constrained times. He and others argue that $5.3 billion for space and Earth sciences is a lot of money, and should not provoke complaints. While some in the space science community are calling for more money (as most program advocates do), others want to focus more on ensuring that NASA wisely distributes what funds are made available among the various disciplines and types of activities (flight programs versus Research and Analysis (R&A), and among small, medium, and large flight programs).

At a March 2 House Science Committee hearing, Chairman Sherwood Boehlert asked representatives of four of our decadal studies to comment on the FY2007 budget request. He stressed, however, that he did not want to hear pleas for more money. Instead, he wanted to understand how the science community would have distributed the $5.3 billion differently from NASA's proposal.

Four representatives of our decadal studies—Berrien Moore for Earth sciences, Fran Bagenal for solar and space physics, Joe Taylor for astronomy and astrophysics, and Wes Huntress for planetary exploration—agreed that the most important area to preserve was R&A because that is the seed corn. In the budget request, most R&A funding would be cut by 15%, and astrobiology would be cut by 50%. Chairman Boehlert pressed the witnesses on this point, asking if they would sacrifice "flagship" missions in order to preserve R&A. With some caveats (such as from those whose flagship missions already have been cut), the witnesses agreed that some flagship missions could be reevaluated, especially those encountering significant cost growth, such as the James Webb Space Telescope (JWST). (The hearing can be viewed as an archived webcast on the House Science Committee's website: http://www.house.gov/science. See Hearings|Full Committee|March 2, 2006)

Science Mission Directorate Associate Administrator Mary Cleave, the fifth witness at the hearing, appeared open to the possibility of reconsidering the R&A cuts. Dr. Griffin subsequently indicated his own willingness to reassess the situation. But he also stressed that he will only listen if there is consensus among the scientific community. As quoted in the April 3 issue of *Aviation Week & Space Technology*, he said that "If there is a compelling trend in one direction or other, I would be heavily motivated to go where they'd like us to go…. If, as might equally well happen, there is a cacophony of opinions but no clear center of mass for any one direction, then we'll probably stick with what I've got, because that would tell you our budget is making everyone about equally unhappy."

The SSB's Ad Hoc Committee on Balance in NASA's Science Programs is currently writing a report that attempts to reach a consensus. We hope to have it completed in early May. If we are successful in finding consensus, it could be influential in determining final funding levels for FY2006 and FY2007, especially in R&A and small missions.

One challenge NASA faced in choosing its science priorities during formulation of the FY2007 budget was the lack of advice from the internal scientific advisory subcommittees that traditionally guide such decisions and provide a two-way dialog between the agency and the science community. Those subcommittees were not in place during NASA's FY2007 budget formulation process. SMD Associate Administrator Mary Cleave is working toward reestablishing those subcommittees in May, which could help avoid dramatic surprises for the science community in the future.

Much work remains to be done to determine how to respond to the current budget climate, how to best spend the $5.3 billion, and how to ensure the survival of key elements of the life and microgravity sciences community so critical questions can be answered about those aspects of future human exploration of space.

Since 1958, the SSB has provided independent scientific and programmatic advice to NASA and other government agencies and served as a bridge between the government and the scientific community. We look forward to continuing our efforts to help ensure a strong U.S. space program, and I personally am excited about working with the stellar volunteers who serve on our Board and committees and the superb staff of the Space Studies Board and the National Academies.

Marcia S. Smith
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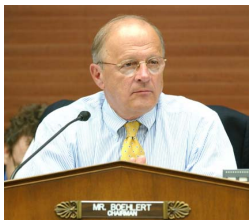
House Science Committee Chairman Boehlert to Retire from Congress



Representative Sherwood Boehlert (R-NY), Chairman of the House Science Committee and a staunch advocate of scientific research, has decided not to run for reelection after 24 years in Congress. Chairman Boehlert is in the sixth year of his term-limited 6-year chairmanship of the Science Committee. He announced his retirement on March 17, 2006 (http://www.house.gov/boehlert/pr_060317_boehlertretirement.htm).

Mr. Boehlert has been a strong champion of NASA, particularly its scientific research programs. Among his many accomplishments was last year's passage of the 2005 NASA Authorization Act which embraced President Bush's Vision for Space Exploration, but also emphasized that NASA must ensure a balance among its science, aeronautics, and human spaceflight activities.

At a March 2, 2006 hearing on NASA's FY2007 budget request for the Science Mission Directorate, he said: "…I see science as the most successful aspect of NASA, one that expands the human mind, excites students, pushes technology, provides vital information about our own planet, and helps make the U.S. a world leader. I want to do everything in my power to protect NASA science."

The Space Studies Board will miss Chairman Boehlert and his unfailing support for space science, but we wish him well in whatever new endeavors he undertakes.

BOARD AND COMMITTEE NEWS

- The **Space Studies Board** (SSB) held its 148th meeting at the National Academies' Keck Center in Washington, DC, on March 6-8, 2006 in conjunction with the Committee on an Assessment of Balance in NASA's Science Programs. The meeting time was devoted to reviewing the status of selected ongoing SSB studies, planning near-term consultations with government officials regarding potential future studies and planning the next SSB meeting. The board will meet next at the Johnson Space Center in Houston, TX, on June 13-15, 2006.
- The **Committee on an Assessment of Balance in NASA's Science Programs** met on March 6-8, 2006 to hear from NASA and other government officials about the programs embodied in the FY2007 budget proposals, to receive reports from the SSB standing committee chairs, and to discuss the committee's response to its charge. The committee is preparing the third and final component of the National Research Council's (NRC) advisory response to the FY2005 Congressional Appropriations report mandate to review the science that NASA is proposing to undertake under the space exploration initiative and to develop a strategy by which all of NASA's science disciplines can make adequate progress towards their established goals. The committee aims to complete its report in May 2006.
- The **Committee on Astronomy and Astrophysics** (CAA) did not meet during the quarter. The committee plans to meet in Washington, DC on May 19-20, 2006. At that time the committee expects to hear program overviews from both NASA and NSF.
- The **Committee on Planetary and Lunar Exploration** (COMPLEX) did not meet this quarter to allow the Committee on the Review of the Next Decade Mars Architecture to convene. The committee did, however, conduct a conference call with Andrew Dantzler, the director of NASA's Planetary Science Division, on February 21, 2006. The principal topic of discussion was the status of NASA's solar system exploration missions in light of the president's budget proposals for fiscal year 2007. Following the conference call, the committee drafted comments which were forwarded to the Space Studies Board. The committee will meet next at the National Academies' Keck Center in Washington, DC, on June 5-7, 2006.
- The **Task Group on Organic Environments in the Solar System** (TGOESS) did not meet this quarter. Work on revising the report in response to reviewer's comments is nearing completion.
- The **Committee on the Limits of Organic Life in Planetary Systems** (LIMITS) did not meet this quarter. The committee has completed an initial draft of its final report and anticipates sending the text to the NRC's external reviews in the second quarter of 2006. Publication of the committee's report is expected in the summer of 2006.
- The **Committee on the Origins and Evolution of Life** (COEL) held its first meeting of 2006 in a joint session with the Committee on the Astrobiology Strategy for the Exploration of Mars on January 23-25, 2006 in Irvine, CA. The committee also conducted a conference call with Carl Pilcher, the executive in charge of astrobiology programs at NASA headquarters, on February 16, 2006. The principal topic of discussion was the status of NASA's Astrobiology Program in light of the president's budget proposals for fiscal year 2007. Following the conference call, the committee drafted comments which were forwarded to the Space Studies Board. Subsequent meetings of the committee will take place on May 10-12, 2006 (Washington, DC), September 13-15, 2006 (Boulder, CO) and November 8-10, 2006 (location to be determined).
- The **Committee on Priorities for Space Science Enabled by Nuclear Power and Propulsion** (NUCLEAR) did not meet this quarter and has completed all of its activities. The printed copies of the committee's report were delivered to NASA on March 23, 2006.
- The **Committee for the Review of the Next Decade Mars Architecture** (Mars Architecture) met in Washington, DC, on March 29-31, 2006 and held a subsequent conference call on April 4, 2006. The committee's letter report assessing NASA's Mars exploration plans for the period 2007 to 2016 is scheduled for release in the third quarter of 2006.
- The **Committee on Planetary Protection Requirements for Venus Missions** (VENUS) did not meet this quarter and has completed its activities. The committee's letter report on "Assessment of Planetary Protection Requirements for Venus Missions" was approved for release by the NRC on January 30, 2006 and sent to NASA on February 9, 2006. At the suggestion of NASA's Planetary Protection Officer, the poster paper

"Reassessment of Planetary Protection Requirements for Venus Missions," by J.W. Szostak, R.L. Riemer, D.H. Smith and J.D. Rummel is being prepared for display at the General Assembly of COSPAR in Beijing in July 2006.

- The **Committee on the Astrobiology Strategy for the Exploration of Mars** (Mars Astrobiology) held its first meeting on January 23-25, 2006 in Irvine, CA along with the Committee on the Origins and Evolution of Life. Subsequent meetings of the committee will take place on May 10-12, 2006 (Washington, DC), September 13-15, 2006 in Boulder, CO and November 8-10, 2006 (location to be determined).
- The **Committee on Solar and Space Physics (CSSP)** published, in February 2006, a pre-publication copy of its report *Distributed Arrays of Small Instruments (DASI) for Solar-Terrestrial Research: Report of a Workshop*. Final copies of this report are anticipated by April 30, 2006. Approximately half of the committee's members are also members of an NRC committee that is writing a report that will summarize the proceedings from an October 16-20, 2005 conference, "Solar and Space Physics and the Vision for Space Exploration." A particular emphasis of the workshop was on improving predictions of solar energetic particle storms, the solar eruptions that produce them, and the impact of solar storms on Earth, Moon, and Mars environments. A draft of the workshop report was undergoing external peer review at the end of this reporting period; report approval is anticipated during the second quarter.

The committee met on February 24-25, 2006, Washington, DC. Principal agenda items included:

- A briefing by Richard Fisher from NASA HQ on NASA's FY2007 budget for heliophysics,
- Discussions of potential new studies,
- Preparation of briefing materials for presentation to the Space Studies Board study on "An Assessment of Balance in NASA's Science Programs," and
- Discussions with Fran Bagenal regarding her March 2, 2006, testimony to the House Science Committee on implications of the FY2007 budget for heliophysics research and the workforce for heliophysics.

The committee also developed detailed plans for its next study which is anticipated to be a study of the impacts (especially economic) and potential for mitigation of severe space weather events.

- The **Committee on the Solar System Radiation Environment and NASA's Vision for Space Exploration: A Workshop** held several teleconferences to prepare their report for publication. The committee attended the October 2005 workshop on Solar and Space Physics and the Vision for Space Exploration, a cross-disciplinary workshop which examined the radiation environments in the inner solar system and their effects on astronauts and operational systems in space. The committee produced a report which entered external review at the end of March 2006. The committee hopes to release a prepublication version of the report by May 2006. NASA has asked the Aeronautics and Space Engineering Board (ASEB) to consider a long-term study of this issue.
- The **Committee on Earth Studies** (CES) continues to stand down as work continues on the decadal study "Earth Science and Applications from Space: A Community Assessment and Strategy for the Future." However, members of the committee are available to brief agency officials on their fall 2005 publication, *Extending the Effective Lifetimes of Earth Observing Research Missions*. This report, requested by NASA, (1) evaluates the effectiveness of the mission extension paradigm as a means for managing mission life-cycles, (2) assesses whether the NASA Senior Review provides an appropriate foundation to implement an Earth science mission extension process, and (3) identifies modifications to the Senior Review process that could enhance its value to Earth science missions.
- The **Earth Science and Applications from Space: A Community Assessment and Strategy for the Future (ESAS)** decadal survey is led by an 18-member steering (executive) committee and 7 thematically organized study panels:

1. Earth Science Applications and Societal Benefits
2. Land-use Change, Ecosystem Dynamics and Biodiversity
3. Weather (incl. space weather and chemical weather)
4. Climate Variability and Change
5. Water Resources and the Global Hydrologic Cycle
6. Human Health and Security
7. Solid-Earth Hazards, Resources, and Dynamics

During this quarter, the following meetings took place:

- ESAS Steering Committee (January 10-12, Washington, DC)
- Panel on Earth Science Applications and Societal Benefits (January 26-27, Washington, DC)
- Panel on Climate Variability and Change (February 6-7, Irvine, CA)
- Panel on Human Health and Security (March 23-24, Washington, DC)

Representatives from the steering committee and the panels were present on January 30, 2006, in Atlanta, GA, for a "town hall" community forum that was held in conjunction with the annual meeting of the American Meteorological Association. Representatives were also present on February 21, 2006, for a town hall which was held in conjunction with the American Geophysical Union's Ocean Sciences meeting in Hawaii. Copies of the steering committee and panel presentations are available on the survey's public website at: http://qp.nas.edu/decadalsurvey.

By the end of the quarter, 20 of the planned 21 panel meetings had been completed. Panels had completed second drafts of their report chapters and had also identified, prioritized, and provided rough cost estimates for their recommended suite of activities. The next meetings of the survey steering committee will take place in Irvine, California, from May 2-4, 2006, and August 22-24, 2006, in Woods Hole, Massachusetts. The final report from the steering committee, which will include a prioritized list of potential activities to advance Earth science and applications from space, is expected by December 2006.

- The **Committee on Space Biology and Medicine** (CSBM) was mostly inactive during this period, except for various tracking and dissemination activities such as providing requested materials and information on prior reports or assistance to related studies by other committees. The committee chair,

Donald Ingber, is currently representing the past work and recommendations of CSBM in the ongoing SSB study on balance in NASA's science programs.

- The **Committee on Microgravity Research** (CMGR) was mostly inactive during this period, except for various tracking and dissemination activities such as providing requested materials and information on prior reports or assistance to related studies by other committees. The committee chair, Dennis W. Readey, is currently representing the past work and recommendations of CMGR in the ongoing SSB study on balance in NASA's science programs.
- The SSB, working jointly with the **Aeronautics and Space Engineering Board** (ASEB), organized independent reviews of strategic roadmaps that were developed by NASA's Advanced Planning and Integration Office. The **NASA Strategic Roadmaps: Science Panel** delivered its report to NASA in prepublication form on August 2, 2005. The second panel, the **NASA Strategic Roadmaps: Space Station Panel**, delivered its report to NASA in prepublication form on November 22, 2005. Editing of both reports was completed this review period and the published reports were printed and distributed at the end of March.
- Dissemination for the **Committee on Preventing the Forward Contamination of Mars** (PREVCOM) report *Preventing the Forward Contamination of Mars* began on March 27, 2006. A limited number of free copies are available from the SSB Office while supplies last. During the Committee on Space Research (COSPAR) 36th Scientific Assembly in Beijing, China, in July 2006, David Paige will present a summary of the report.
- Dissemination for the **Committee on Principal Investigator-Led Missions** (COMPILED) final report *Principal-Investigator-Led Missions in the Space Sciences* also began March 27, 2006. A limited number of free copies are available from the SSB office while supplies last. The committee officially disbanded on March 31, 2006.
- Work has resumed on identifying members for the **Committee on Large Optical Systems in Space (LOIS)**. The committee is being formed in response to a joint request from NASA and the National Reconnaissance Office. It will conduct a survey and analysis of technology opportunities and issues relevant to development and operation of medium-size and large optical systems in space. Part of the resulting report is expected to be classified. A revised statement of task from NASA was recently received, allowing resumption of committee formation.
- The **Committee on Astronomy Science Centers** is reviewing lessons learned from experience with NASA's ensemble of space astronomy science centers in order to recommend a set of guiding principles and best practices for consideration in making decisions about approaches to meeting the needs of the astronomy community with future science centers. On February 9-11, 2006, the committee met to discuss the Education and Public Outreach (E/PO) efforts at the science centers and to continue drafting the report. The committee heard from Kathleen Lestition (Chandra X-Ray Center), James Manning (STScI), and Michelle Thaller (Spitzer Science Center) about their E/PO efforts. The committee also heard from Nick Cabot (Science Department Chair, Nathan Hale High School, Seattle), Carl Pennypacker (Principal Investigator, Hands-on Universe), and Roberta Tanner (Loveland High School, Loveland, Colorado). These educators provided their views of and advice on the centers' E/PO programs. The committee chair will be visiting the Spitzer Science Center and Michelson Science Center on April 18 and the Chandra X-Ray Center on May 3. The committee will meet next on May 10-12, 2006, in Irvine, CA. The committee expects to produce its final report in late 2006.
- The **Committee on Meeting the Workforce Needs for the National Vision for Space Exploration** held a two-day information-gathering workshop as a part of its first meeting at the National Academies' Keck Center on January 23-25, 2006, in Washington, DC. The workshop was organized to examine relevant workforce demographics and factors that may impact them, future workforce skill needs, and issues that may require further study. The approximately 35 participants included study committee members and representatives from NASA, DOD, NSF, aerospace industry, academia, and several non-government organizations. The committee held its second meeting at the Keck Center on February 22-23, 2006, to gather additional information and to plan its interim report. NASA representatives presented results of workforce analyses and modeling carried out by NASA's Systems Engineering and Institutional Transition Team. The committee also heard presentations from Bureau of Labor Statistics representatives on projections of future labor force supply and demand in aerospace science and engineering, and heard additional aerospace industry perspectives on workforce issues. The committee hopes to release its interim report by late April 2006.

The next meeting of the committee will be on May 8-9, 2006, at the National Academies' Keck Center in Washington, DC.

- The **Committee on Space Research** (COSPAR) Publications Committee, Program Committee, and Bureau meetings were held March 20-23, 2006 in Paris, France. In addition, COSPAR's new Scientific Advisory Committee (CSAC), chaired by Prof. Lennard A. Fisk of the University of Michigan, held its first meeting. The advisory committee emerged from COSPAR's strategic visioning exercises held during 2004-2005. Other changes from that exercise include efforts to further involve students and young scientists in COSPAR activities, and increased attention to education. Plans are underway for the organization's 36th Scientific Assembly, which will be held in Beijing, China in July 2006. <http://www.cosparhq.org/Meetings/meetings>. Abstracts for the meeting were due February 17, 2006. COSPAR will be moving from its current location in Paris to an as-yet-undetermined location by the end of 2006 because the French government, which owns the building housing COSPAR and other units of the International Council of Science (ICSU), has sold it.

CONGRESSIONAL TESTIMONY

On March 2, 2006, the House Science Committee held a hearing on NASA's FY2007 request for the Science Mission Directorate. Each of the four SSB decadal surveys was represented by someone who participated in the study, although all were testifying in their individual capacities, not as representatives of the SSB or the Academies. The four witnesses were: Joseph Taylor for astronomy and astrophysics, Fran Bagenal for solar and space physics, Wes Huntress for planetary exploration, and Berrien Moore for Earth sciences. The texts of their prepared statements follow. They also are available, along with an archived webcast of the hearing, on the Science Committee's website [http://www.house.gov/science]. Click on "hearings" on the left menu, then "full committee," then the hearing listed for March 2, 2006.

Statement of

Joseph H. Taylor, Jr., Ph.D. NL.
James S. McDonnell Distinguished University
Professor of Physics
Princeton University

Before the
Committee on Science
The U.S. House of Representatives

MARCH 2, 2006

Mr. Chairman, Ranking Minority Member, and members of the committee: thank you for inviting me to testify. My name is Joseph Taylor and I am the James S. McDonnell Distinguished University Professor of Physics and former Dean of the Faculty at Princeton University. I served in 1998–2000 as co-chair of the National Academies Astronomy and Astrophysics Survey Committee, but my comments today represent my own opinions, informed by discussions with many colleagues in the U.S. astronomy community.

As you know, the astronomy community has a long history of creating, through the National Research Council (NRC), broad surveys of the field at ten-year intervals. These surveys lay out the community's research goals for the next decade; they identify key scientific questions that are ripe for answering, and they propose new initiatives that will make those goals achievable. The most recent decadal survey, entitled *Astronomy and Astrophysics in the New Millennium*, was released in the year 2000.[1] I have been asked to answer the following questions from my perspective as the co-chair of the committee that produced that report:

1. What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?

2. Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY 07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?

3. How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY 07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

In the balance of my testimony I shall address all three questions.

In previous decades the NRC decadal survey was an activity unique to the astrophysical sciences. The most recent survey involved the direct participation of 124 astronomers as committee and panel members; moreover, these people received input from many hundreds more of their colleagues. Altogether, a substantial fraction of the nation's astronomers were in some way involved in the creation of the report. By gathering such broad community input, the survey process creates a document that reflects the consensus opinion of the active researchers in the field. The value of this advice to NASA and the National Science Foundation has been demonstrated in many ways. It clearly helped to motivate NASA's requests for the NRC to conduct similar surveys for planetary science,[2] solar and space physics,[3] and earth science.[4]

The feature of a decadal survey that distinguishes it from summaries of other fields of science is the prioritized list of recommended initiatives. This list is a valuable tool for strategic planning, and it receives considerable attention. As with the use of any tool, some judgment is required in its application. Science priorities drive the assigned priorities of the projects. The science priorities are based on the output of the research community throughout the country, including its probable extrapolation into the future. The most serious impact of the President's FY2007 budget proposal is that it threatens to significantly decrease this output by cutting the research and analysis grants lines by 15%. At a time when the administration has proposed an American Competitiveness Initiative and many members of Congress have expressed strong support for increasing research in the physical sciences, this reduction seems counter-productive at best. For the past decade NASA has provided a majority of the nation's research support in astronomy and astrophysics. The proposed reductions are therefore of considerable concern to the astronomy community.

The damage caused by these budget cuts is compounded by the fact that their impact will be disproportionately felt by the younger members of the community — the assistant professors, post-doctoral trainees, and graduate students. Without research

support to pay for their time, this group will be forced to turn to other fields. Many will leave the sciences altogether, and other bright young people will decide not to enter. In a similar vein, severe reductions in the flight rate of NASA's Explorer line of smaller, lower cost missions will be damaging to the field and particularly its ability to attract and retain younger talent. The Explorer satellites have been extremely cost effective and have often been an entry point for younger researchers into mission development and project management. The scientists and engineers who will build and use tomorrow's Great Observatories are building today's Explorers. It would be a tragedy to drive these people away from space science.

It is easy to identify specific impacts of these cuts and others in the budget proposal, but I wish to call attention to a broader impact that addresses your question about the field's ability to retain scientists and engineers. The administration is proposing to reduce near term opportunities in order to fully fund large, long-term missions. At the same time it is terminating a long-planned, nearly completed facility called SOFIA and indefinitely deferring an entire program called "Beyond Einstein." I believe that the field of astronomy can sustain itself through lean budgetary times if there is opportunity on the horizon, but this budget proposal sends the message that even nearly completed missions may never be flown. It does not provide the positive view of the future that will keep members of the community engaged and attract bright young people to the field.

The primary goal of the year 2000 Decadal Survey was to provide a vision for a sustainable national effort in astronomy and astrophysics — one that would build on the enviable position of leadership in astronomy that America has developed over the past half century and more. I do not believe that the FY2007 budget submission is consistent with this vision. I believe that NASA is trying to follow the survey recommendations, and I appreciate that it has protected the highest priority mission, the James Webb Space Telescope, and the crown jewel of the space astronomy missions, the Hubble Space Telescope, in the face of significant cost increases. However, as I mentioned when I appeared before you last year to discuss the Hubble Space Telescope, I do not believe that the highest priority missions should be implemented without regard to cost or impact on the overall program. The Decadal Survey recommended that NASA have a mission portfolio with a mix of large, moderate, and small missions. The FY2007 budget proposal is weighted to an unhealthy extent towards the large missions. The Decadal Survey recommended that NASA maintain adequate funding in research and analysis grants to "ensure the future vitality of the field." I believe that the proposed reduction in the grants line is not consistent with this recommendation.

One very significant scientific development has taken place since the Decadal Survey was released. Confirmation of the universe's accelerating rate of expansion and the existence of some form of "dark energy" have stimulated new research efforts across astronomy, astrophysics, and fundamental particle physics. The NRC's 2003 report *Connecting Quarks with the Cosmos* puts these discoveries into the broader context of understanding the universe and the physical laws that govern it. NASA worked with the community to develop its Beyond Einstein plan, synthesizing the recommendations of the Decadal Survey and the 2003 report into a widely praised strategy for investment in high energy astrophysics. NASA also participated in an interagency process headed by the Office of Science and Technology Policy which produced a detailed plan for NASA, the NSF, and the Department of Energy to move forward in this area. The NSF and DOE are implementing many of these recommendations by increasing research support and planning investments in new instruments and missions, but NASA continues to push the Beyond Einstein program into the indefinite future.

National priorities outlined in the FY2007 budget submission present NASA and the astronomy and astrophysics community with significant challenges. I do not believe, however, that a new decadal survey is needed immediately. The study we completed a little over five years ago produced a positive and forward looking document that tried to capture the scientific opportunities ahead of us. Of course science has progressed in the intervening five years, but the priorities we set still look about right. Conducting a new survey at this time would set an unfortunate precedent and encourage undesirable second-guessing at any time in the future. With these things said, it is also clear that some sort of advice from the community is needed now. In the 2005 NASA Authorization Act, Congress requested that the NRC provide NASA with a mid-decade performance assessment for each of its scientific programs. The NRC and NASA have agreed to begin this process with the astronomy and astrophysics program, and the NRC is working now to assemble a review panel. One of the goals of this study will be to provide a feasible implementation plan for the rest of this decade. Such a plan should form a solid foundation on which to conduct the next decadal survey at its normal time, near the end of this decade.

One of the keys to crafting a feasible program is to acquire accurate information on the resources necessary to complete each mission. We attempted to gather such information in carrying out the 2000 Decadal Survey, but in retrospect it is clear that our efforts were inadequate. I believe that the correct procedure is for NASA to set up a task force to work with centers and contractors to improve the reliability of the cost, schedule and technology risk estimates, including proper contingencies, for each of the selected missions. Serious departures from these projections in the future should be grounds for consideration of mission cancellation, even for large missions of high priority.

In addition to these specific proposals, I believe it is essential that NASA work harder to communicate with its scientific community — the community that has contributed so much to the agency's successes over the years. Part of the difficulty in this particular budget cycle is that NASA's advisory bodies have been in disarray, leading to a perceived lack of community input into the agency's decision-making process. I do not believe there is a foolproof formula for setting priorities across different scientific disciplines, but it is clear that each of NASA's science disciplines must remain independently healthy. Rapid budgetary fluctuations can threaten that condition. I am confident that if the priority-setting process is done well it must include dialogue and consultation with representatives of the appropriate scientific communities. Without such discussion, budget proposals such as this one run the risk of touching off efforts outside the normal, proven planning channels to save troubled programs. This situation would eliminate one of the primary strengths of the decadal survey process: priorities based on the informed consensus of a highly competitive but ultimately cooperative scientific community.

To summarize, I believe that the FY2007 NASA budget proposal does not present a program that can provide the nation with a healthy and productive astronomy and astrophysics program. The budget proposal reduces astronomy and astrophysics at NASA by 20% over the five-year runout, before inflation is taken into consideration. The proposal damages programs that are necessary for the sustainability of a healthy research community, and it is skewed too heavily towards large missions. It may be that in the current budget climate, NASA is unable to provide the necessary resources to keep the program healthy. If so, NASA must do a better job of working with the community in order to find the best solutions to the challenges that lie ahead.

Thank you for your attention, and I will be pleased to answer questions.

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[1] *Astronomy and Astrophysics in the New Millennium*, NRC, 2001.
[2] *New Frontiers in the Solar System*, NRC, 2003.
[3] *The Sun to the Earth – and Beyond*, NRC, 2003.
[4] Study underway - http://qp.nas.edu/decadalsurvey

Statement of

Fran Bagenal
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Before the
Committee on Science
House of Representatives

MARCH 2, 2006

Good morning, Mr. Chairman and members of the Committee. My name is Fran Bagenal and I am a professor at the University of Colorado. I served on the committee for the NRC decadal survey for solar and space physics and chaired a committee that assessed the role of solar and space physics in space exploration.

I am here today to provide an evaluation of the impact of the NASA's FY07 budget on solar and space physics – a field of research that corresponds to what is labeled, as of last week, the Heliophysics Division of NASA's Science Mission Directorate. Heliophysics has previously been called Sun-Earth Connections (SEC) and, until last week, sat with Earth Science within Earth-Sun Systems. This evaluation yields six conclusions that are summarized as follows:

1. NASA's investment in science has had a high payoff; it has spurred advances in leading edge technologies and has been instrumental in educating the next generation of scientists.
2. The claimed increase in science's share of the NASA budget is not reflected in science activity and in part arises from a change in accounting rules.
3. There will be a precipitous drop in launches of science missions beginning in 2010 and continuing forward.
4. The Explorer program is experiencing dramatic cuts and set-backs.
5. The Sounding Rocket Program, which serves our nation as a space academy, is withering after more than a decade of flat funding.
6. The FY07 budget makes major cuts in the Research and Analysis Program, which will affect disproportionately the youngest space scientists, and place the health of the space science "workforce" at risk.

To understand these conclusions I would like to begin by giving some context for this area of science.

Heliophysics

The Sun is the source of energy for life on Earth and is the strongest modulator of the human physical environment. In fact, the Sun's influence extends throughout the solar system, both through photons, which provide heat, light, and ionization, and through the continuous outflow of a magnetized, supersonic ionized gas known as the solar wind. The realm of the solar wind, which includes the entire solar system, is called the heliosphere. In the broadest sense, the heliosphere is a vast interconnected system of fast-moving structures, streams, and shock waves that encounter a great variety of planetary and small-body surfaces, atmospheres, and magnetic fields. Somewhere far beyond the orbit of Pluto, the solar wind is finally stopped by its interaction with the interstellar medium.

Thus, interplanetary space is far from empty − an often gusty solar wind flows from the Sun through interplanetary space. Bursts of energetic particles arise from acceleration processes at or near the Sun and race through this wind, traveling through interplanetary space, impacting planetary environments. It is these fast solar particles, together with galactic cosmic rays, that pose a threat to exploring astronauts. The magnetic fields of planets provide some protection from these high energy particles, but the protection is limited and variable, and outside of the planetary magnetospheres there is no protection at all. Thus, all objects in space − spacecraft, instrumentation and humans − are exposed to potentially hazardous penetrating radiation, both photons (e.g., x-rays) and particles (e.g., protons, heavy ions and electrons). Just as changing atmospheric conditions on Earth lead to weather that affects human activities on the ground, the changing conditions in the solar atmosphere lead to variations in the space environment − space weather- that affects activities in space.

Decadal Survey & Vision for Space Exploration

In 2002, the National Research Council published the first decadal strategy for solar and space physics: *The Sun to the Earth—and Beyond: A Decadal Strategy for Solar and Space Physics.*[1] The report included a recommended suite of NASA missions that were ordered by priority, presented in an appropriate sequence, and selected to fit within the expected

resource profile for the next decade, which was anticipated to increase substantially through ~FY08.

In early 2004,[2] NASA proposed to adopt major new goals for human and robotic exploration of the solar system, consistent with the Bush Administration's Vision for Space Exploration. Any exploration will depend, in part, on developing the capability to predict the space environment experienced by exploring spacecraft and humans. Also in 2004, the Space Studies Board of the National Research Council tasked a committee to assess the role of solar and space physics in NASA's Exploration Vision.[3] This committee stated that:

> NASA's Sun-Earth Connection program depends upon a balanced portfolio of spaceflight missions and of supporting programs and infrastructure, which is very much like the proverbial three legged stool. There are two strategic mission lines-Living With a Star (LWS) and Solar Terrestrial Probes (STP)-and a coordinated set of supporting programs. LWS missions focus on observing the solar activity, from short-term dynamics to long-term evolution, that can affect the Earth, as well as astronauts working and living in near-Earth space environment. Solar Terrestrial Probes are focused on exploring the fundamental physical processes of plasma interactions in the solar system. A key assumption upon which the LWS program was designed was that the STP program would be in place to provide the basic research foundation from which the LWS program could draw to meet its more operationally oriented objectives. Neither set of missions can properly support the objectives of the Exploration Initiative alone. Furthermore, neither set of spaceflight missions can succeed without the third leg of the stool. That leg provides the means to (a) conduct regular small Explorer missions that can react quickly to new scientific issues, foster innovation, and accept higher technical risk; (b) operate active spacecraft and analyze the LWS and STP mission data; and (c) conduct ground-based and sub-orbital research and technology development in direct support of ongoing and future spaceflight missions.

I will return to this issue of balance between these 3 legs of basic, applied and supporting research later in my testimony.

This re-evaluation of the Decadal Survey endorsed the original scientific and mission priorities – emphasizing a balance in the fundamental and applied aspects of space physics - but recognized that the schedule of missions would have to be considerably stretched out to fit a leaner budget.

Science Mission Directorate FY07 Budget

With this background, let me proceed to NASA's FY07 budget. First, may I commend Administrator Dr. Griffin's bold leadership of NASA and his clear command of the technical issues involved. we all recognize the enormous challenge of enacting the Vision for Space Exploration while fulfilling international obligations associated with Space Station. NASA is being asked to do Apollo with a post-Apollo budget. Yet we must also remember that science is a vital part of the Vision for Space Exploration. I repeat the refrain "Exploration without science is just tourism."

In his February 16th statement to this committee, Dr. Griffin quoted that fraction of the NASA budget allocated to science had grown from 24% to 32% between 1992 and 2007. These figures were emphasized in his oral presentation with the explicit implication that this fraction should be reduced by having the science budget slow down to a 1% growth rate while NASA as a whole grows three times faster. First of all, I do not claim to know what fraction of the NASA budget is the "correct" value to be spent on science. But I submit that the dramatic close-up views of our Sun from SOHO and Trace as well as the exciting new worlds revealed by Voyager, Hubble, Mars rovers, and Cassini have permanently changed the American people's view of space science. ***Investment in science has paid off for NASA – not only in terms of cultural and intellectual benefits but also in enabling technology and inspiring young scientists and engineers.***

Secondly, I accept that the science budget has seen net growth – and a third of the NASA's $17 billion budget is a substantial amount to spend on science. The reason for this growth is partly because of demonstrated successes. But I point out that over the past 15 years there have been significant changes in the way NASA has been bookkeeping different components of the budget (e.g. project management & operations, salaries of civil servants, and particularly launch costs which have doubled in the past ~5 years). I suggest that the quoted 8% increase in the share of the NASA budget being labeled as science does not necessarily reflect a corresponding increase in scientific activity. It might be useful for your committee to task one its support agencies; for example, the Government Accountability Office, to evaluate of how these budget figures are tracked. At the very least, I caution against taking this simple statistic at face value and using it to rationalize the diminishment of what has been one of NASA's great successes - science.

Heliophysics Budget

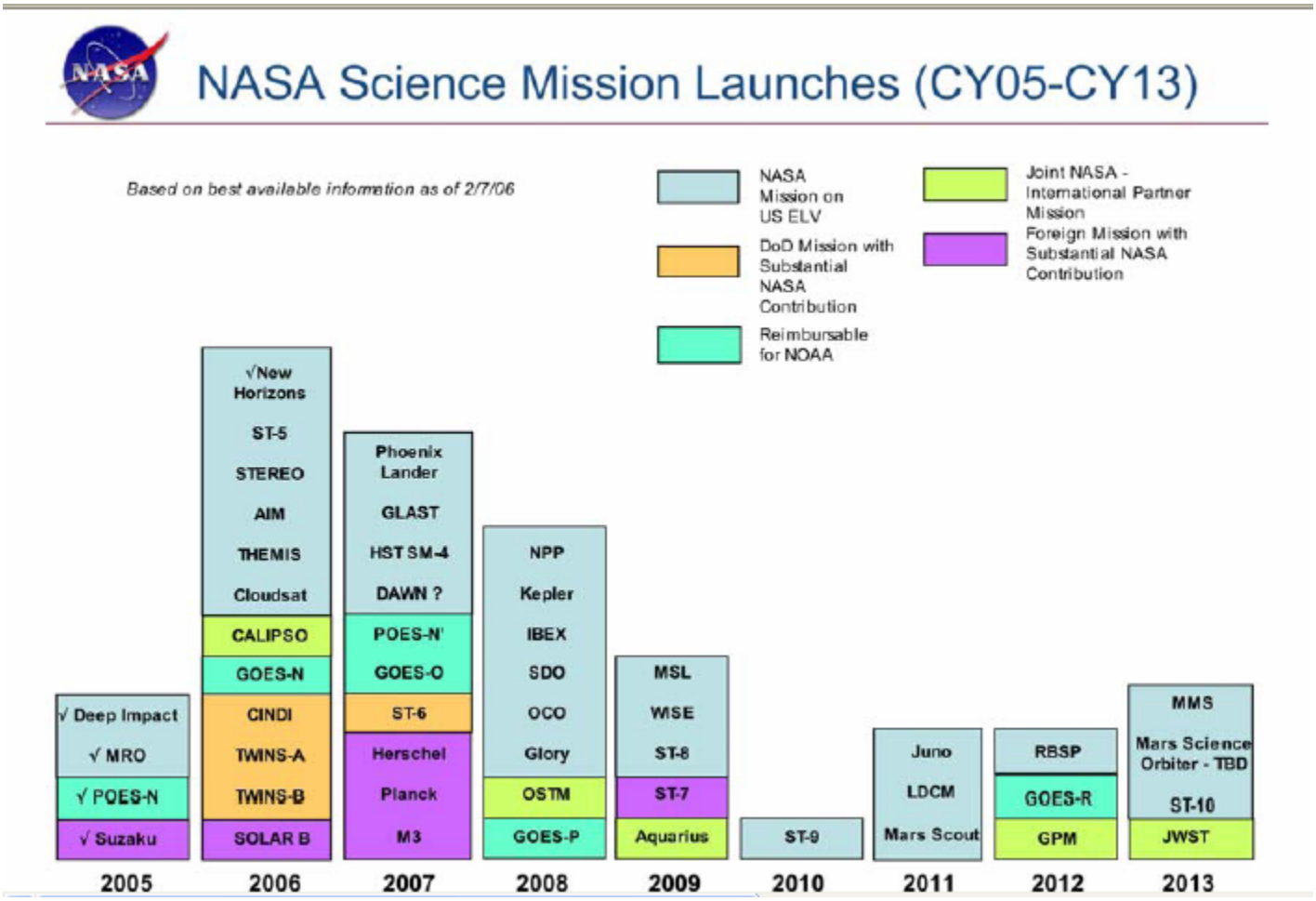
I have been asked to address the following specific questions:

1. *What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?*

Science Mission Launches

The impact of elimination of growth in SMD is most dramatically illustrated by the following chart of science mission launches for the next seven years. An impressive list of missions to be launched in the next couple of years is followed by a precipitous drop to only one launch in 2010 (ST-9, a small technology demonstration mission) and few launches per year thereafter.

Since each mission takes several years of development and construction before launch (~3 years for small missions, over a decade for the largest missions) this paucity of missions beyond 2010 reflects a slowdown in mission opportunities over the past



~5 years and a lack of launch opportunities for several more years. Factors contributing to this dearth of launches are the escalation in launch costs, the impact of full-cost accounting, the under-costing of larger missions, and – most significantly – the elimination of any funding wedge for new missions from here onwards. ***The net result is that there is a significant gap during which it is inevitable that expertise will be lost and it will be hard to attract and train junior scientists and engineers*** - the very people who will be needed to implement the Vision for Space Exploration. ***While the lack of any large missions on the horizon is a concern, the priority for Heliophysics must be a steady cadence of smaller missions.***

The Explorer Program

In the past, the Explorer program has offered frequent opportunities to carry out small and medium sized missions that can be developed and launched in a short (approximately four-year) timeframe. The Explorer Program straddles both the Heliophysics and Astrophysics Divisions with roughly equal numbers of launches in each division.

These focused missions address science of crucial importance to these two division roadmaps and NRC Decadal Surveys: The 2004 NRC report "Solar and Space Physics and Its Role in Space Exploration" states that; Explorers "*are the lifeblood of SEC research because they provide core research, flexibility, innovative technologies, and invaluable training for the next generation of workers for our nation's space enterprise. The Explorer program provides innovative, fast-response missions to fill critical gaps.*" The report recommends "*these programs should continue at a pace and a level that will ensure that they can fill their vital roles in SEC research*". The 2001 NRC report "Astronomy and Astrophysics in the New Millennium" finds that "*the Explorer program is very successful and has elicited many highly innovative, cost effective proposals for small missions from the community.*" Specifically they recommend "*the continuation of a vigorous Explorer program,*" and that "*NASA should continue to encourage the development of a diverse range of mission sizes, including small, moderate, and major, to ensure the most effective returns from the U.S. space program.*"

In the last decade, 10 Explorers were launched; 6 small explorers (SMEX) and 4 medium explorers (MIDEX). These have allowed NASA to respond quickly to new scientific and technical developments, and have produced transformational science, including:

- The best determination of the age of the universe: 13.7 billion years.
- Images of solar flares that show that ions and electrons are accelerated in different locations.
- The discovery of "baby" galaxies still in the process of forming, long after the vast majority of galaxies formed during the early universe

- Measurements of record-speed solar winds (at ~5 million mph) from the large "Halloween" 2003 solar eruptions.
- The discovery that the plasmasphere rotates with the Earth at only 85-90% of the Earth's rotation rate as opposed to the 100% assumed by all models of magnetospheric convection.
- Direct evidence that galactic cosmic rays originate in associations of massive stars (where most supernovae occur).
- Proof that short-duration gamma-ray bursts (lasting less than 2 seconds) have a different origin than long bursts, likely resulting from the fiery mergers of binary neutron stars.
- These are a small fraction of highlights selected to illustrate the astounding breadth and productivity of the program.

The Explorer program has taken dramatic cuts in the last few budget cycles, resulting in:

- The cancellation – for purely budgetary reasons – of a peer-reviewed, selected mission, the *Nuclear Spectroscopic Telescope Array (NuSTAR)* SMEX, chosen (along with the *Interstellar Boundary Explorer (IBEX)*), from the 2002 announcement that solicited two flight missions.
- Delay in the next Announcement of Opportunity until mid 2008 at the soonest (associated mission launch beyond 2014).

The result is a minimum gap from 2008 – 2014 without any Explorer launch, in a program that is vital to both Heliophysics and Astrophysics, and which in the past has seen an average of one launch per year.

As noted in numerous NRC reports, in addition to its scientific importance, there are compelling programmatic, technical and educational reasons to maintain a line of small and moderate-sized competed missions. Explorers have strong involvement of the university community (eight of the ten most recent Explorers have been led by university scientists), and they provide an excellent training ground for young experimental researchers, scientists, engineers and managers, many of whom go on to play lead roles in large missions. The time from development to launch is consistent with PhD degree programs, as well as timescales for the career development of young professional scientists.

This decimation of the Explorer program will have a lasting and significant impact on the Nation's academic research base. Universities and research laboratories make significant internal investments in infrastructure to support experimental space science. Decisions on faculty and staff hires, on accepting graduate students, and the institutional investment in specialized laboratory facilities all depend on existence of a vital research and analysis (R&A) program, and opportunities to develop instrumentation for space flight. Both of these are threatened in the current NASA budget. In particular, the cancellation of missions after they have completed the arduous competitive process and been selected, as happened in the most recent budget process, is a particularly dangerous precedent. Universities, research laboratories, and their international collaborators necessarily rely on the well-established Explorer selection process in their decision to undertake such long term commitments. ***The precedent will be detrimental to the strong partnership between NASA and university researchers, a partnership that has been key to much of NASA's scientific productivity and has provided critical opportunities for developing scientists and engineers in experimental space science.***

Suborbital Sounding Rocket Program

Suborbital sounding rocket flights and high-altitude scientific balloons can provide a wide range of basic science that is important to meeting Heliophysics program objectives. For example, sounding rocket missions targeted at understanding specific solar phenomena and of the response of the upper atmosphere and ionosphere to those phenomena have potentially strong relevance. This science is cutting-edge, providing some of the highest-resolution measurements ever made and, in many cases, providing measurements that have never been made before.

The Suborbital program serves several important roles, including:

- Conducting important scientific measurements in support of orbital spaceflight missions,
- Providing a mechanism to develop and test new techniques and new spaceflight instruments, and
- Providing effective training to develop future experimental scientists and engineers.

Development of new scientific techniques, scientific instrumentation, and spacecraft technology is a key component of the Suborbital program. Many of the instruments flying today on satellites were first developed on sounding rockets or balloons. The low cost of sounding rocket access to space fosters innovation: instruments and technologies warrant further development before moving to satellite programs. Development of new instruments using the Suborbital program provides a cost-effective way of achieving high technical readiness levels with actual spaceflight heritage.

The fact that any long-term commitment to space exploration will place a concomitant demand on the availability of a highly trained technical work force makes the training role of the Suborbital program especially important. For example, a 3-year sounding rocket mission at a university provides an excellent research opportunity for a student to carry a project through all of its stages—from conception to hardware design to flight to data analysis and, finally, to the publication of the results. This "hands on" approach provides the student with invaluable experience in understanding the spaceflight mission as a whole. Indeed, over 350 Ph.D.s have been awarded as part of NASA's sounding rocket program. Not only have some of these scientists have gone on to successfully define, propose, and manage bigger missions such as Explorer, many more have brought valuable technical expertise to private industry and the government workforce.

NASA budgets for the Suborbital Sounding Rocket Program have remained flat. When one allows for inflation and the

dramatically escalating launch costs, the net effect is a significant reduction in the capabilities of the program. ***Given the valuable educational, training and technology development roles of sounding rockets, any small saving derived from limiting this minor program has a major impact on future technical capabilities.***

Research and Analysis Programs

Research and Analysis (R&A, sometimes called Supporting Research and Technology SR&T) programs are crucial for understanding basic physical processes that occur throughout the Sun-heliosphere-planet system, and for providing valuable support to exploration missions. The objectives of R&A programs include:

- Synthesis and understanding of data gathered with spacecraft,
- Development of new instruments,
- Development of theoretical models and simulations, and
- Training of students at both graduate and undergraduate levels.

R&A programs support a wide range of research activities, including basic theory, numerical simulation and modeling, scientific analysis of spacecraft data, development of new instrument concepts and techniques, and laboratory measurements of relevant atomic and plasma parameters, all either as individual projects or, in the case of the SEC Theory program, via "critical mass" groups. Theory and modeling, combined with data analysis, are vital for relating observations to basic physics. Numerical modeling can also be a valuable tool for mission planning. Insights obtained from theory and modeling studies provide a conceptual framework for organizing and understanding measurements and observations, particularly when measurements are sparse and when spatial-temporal ambiguities exist. Theory and modeling will be especially important in the context of the space exploration initiative as exploration missions become more complex and the need for quantitative predictions becomes greater. ***These programs also are especially valuable for training students, at both the undergraduate and the graduate level, who will likely play a vital role in the NASA space exploration initiative or join the larger workforce as capable scientists/engineers/managers who cut their teeth on rigorous problems.***

NASA administration has suggested that the 2010 mission gap justifies an immediate 15% cut in R&A across the Science Mission Directorate. The high launch rate in 2006, the extensive list of on-going productive missions and the Nation's need for a technically-trained workforce all argue that R&A should be increased rather than cut.

When it comes to shear science productivity, R&A grants deliver the most "bang for the buck." These usually 3-year grants of ~$100k/year are highly competitive with only the very best 10-20% being selected via rigorous peer review. Even the most established scientists have to compete with everyone else. R&A programs provide the main basis of support for junior scientists – graduate students and post-doctoral researchers. ***Any cutbacks to R&A acutely impacts the most vulnerable and productive sector of space science.***

2. *Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the most recent National Academies Decadal Survey that you released? Have there been any developments since the Decadal Survey that need to be taken into account, and has NASA considered those? Given the FY07 budget request, do you see any need to update the most recent survey or to change the process for the next Decadal Survey?*

The 2004 NRC report, *Solar and Space Physics and Its Role in Exploration,* examined the 2002 Decadal Survey made the following three recommendations:

1. *To achieve the goals of the exploration vision there must be a robust SEC program, including both the LWS and the STP mission lines, that studies the heliospheric system as a whole and that incorporates a balance of applied and basic science.*
2. *The programs that underpin the LWS and STP mission lines -- MO&DA, Explorers, the suborbital program, and SR&T -- should continue at a pace and level that will ensure that they can fill their vital roles in SEC research.*
3. *The near-term priority and sequence of solar, heliospheric, and geospace missions should be maintained as recommended in the decadal survey report both for scientific reasons and for the purposes of the exploration vision.*

These recommendations remain valid today. The mission priorities within the basic science (STP) and applied science (LWS) mission lines as listed in the original Decadal Survey are generally reflected in the Heliophysics budgets for these two mission lines. Where NASA has deviated from the Decadal Survey is in putting greater weight on Living With a Star missions and losing the balance between applied and basic science. Such a priority of emphasizing short-term capability of predicting space weather over the long term goal of understanding the underlying physical principles may have some practical expedience. A more critical issue, however, is the fact that small missions and supporting research have not kept pace. If these programs - the components that comprise the third leg of the stool and the training grounds for new scientists and engineers - are allowed to wither, Heliophysics will quite quickly topple over.

The 2002 Decadal Survey, *The Sun to the Earth-and Beyond,* was the first conducted by the solar and space physics community (though smaller NRC committees have generated many shorter planning documents). The Decadal Survey involved hundreds of scientists in discussions that spanned nearly two years. The scientific priorities set out the survey remain valid today and I see no community movement to change them. But Decadal Surveys are not just a list of science priorities. To design a coherent program across a decade, it is essential to have a realistic budget profile as well reasonably accurate estimates of both technical

readiness and costs of each mission. he Decadal Survey committee worked hard with engineers and NASA management to develop realistic mission costs and a program architecture that fit within budget profiles anticipated in FY03 budget. But changes to the budget profile in FY04 necessitated a substantial stretching of the mission schedule in the 2004 re-assessment of the Decadal Survey in light of the Vision for Space Exploration.[4] Furthermore, under-costing of just a few missions – Big Digs in space – wreck havoc with even the best-laid plans. The scientific community needs to work with NASA to find ways to accurately cost missions, particularly large missions (e.g., by applying lessons learned from management of smaller, PI-led missions as appropriate and greater accountability).

3. How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY07 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

Each of NASA's scientific themes makes breakthrough discoveries that hit the press headlines. Rather than distinguish between them, I would argue that budget priorities be made within each division and, should a project exceeds its budget, any accommodation be made within the division. This would enforce accountability.

NASA conducts an outstanding program of scientific research within its Science Mission Directorate. The market place for scientific ideas – whether for a $100,000/yr research grant or a $1 billion mission – is a highly competitive world where only the very best ideas survive. NASA's science missions excite the public's interest in the universe around them, inspire young students to study math and science, and provide opportunities to generate a technically-trained workforce who contribute to the Nation's economy. Heliophysics not only has cultural and intellectual value but also adds practical and economic value as the Nation embarks on its next wave of space exploration.

[1] National Research Council, *The Sun to the Earth--and Beyond: A Decadal Strategy for Solar and Space Physics*, The National Academies Press, 2002
[2] National Aeronautics and Space Administration, *The Vision for Space Exploration*, NP-2004-01-334-HQ, NASA, Washington, DC., 2004.
[3] National Research Council, *Solar and Space Physics and Its Role in Space Exploration*, The National Academies Press, 2004.
[4] See charts on page 26 of Solar and Space Physics and Its Role in Space Exploration, The National Academies Press, 2004.

Statement of

Dr. Wesley T. Huntress, Jr.
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Before the
Committee on Science
U.S. House of Representatives

MARCH 2, 2006

Mr. Chairman and Members of the Committee:

I am grateful for the opportunity to testify before you today. I have appeared before this Committee many times in my former job as the NASA Associate Administrator for Space Science, and few times since. I now appear before you to address concerns about the future of America's earth and space science in NASA's proposed FY07 budget.

The top line for NASA

I am an advocate for the scientific exploration of space—using both robotic and human elements—with the emphasis on *scientific* exploration. I also believe in the President's new Space Policy and that the CEV is the right way to start. But this FY07 budget proposes to implement the 2-year old Vision for Space Exploration without sufficient funding, and as a consequence does considerable damage to NASA's robotic, scientific exploration program. NASA's plans have been called Apollo on steroids, but the budget provided is Apollo on food stamps.

Two years ago when the President released his Vision, he provided an FY05 budget proposal with new funds in the five-year run out that would support it. In the intervening years, the Administration has reduced this budget to the point where the plan is insupportable. Last year, the Administration cut that budget, forcing the agency to take the money from aeronautics and technology funding. This year, the Administration has reduced the budget yet again, forcing the agency to take an even larger chunk of money from the only enterprise left undamaged in the agency—science.

The White House wants U.S. obligations to the international space station partners to be honored, the space shuttle flown as many times as necessary to complete the station's construction, and a replacement for the Shuttle (the Crew Exploration Vehicle, or CEV) flying by 2014. The only problem is that these requirements were handed to NASA without the $3 billion to $5 billion necessary for flying the required number of Shuttle flights to complete space station construction. This forced the NASA administrator to cannibalize the agency's science program even though he promised last year not to transfer "one thin dime" from scientific exploration into human spaceflight.

The President's Space Policy is not just about human space flight. The very first goal stated in the vision is to "implement a sustained and affordable human and robotic program to explore the solar system and beyond." The vision further advocates that

we "conduct robotic exploration across the solar system for scientific purposes and to support human exploration." This eye of the vision seems to have lost its sight.

The top line for NASA Science

The Administration's 2007 budget proposal removes $3.07 billion from the previously planned 5-year run out of the Earth and space science budget. Of this, $2.99 billion is to come from solar system exploration alone. Of the several disciplines in earth and space science, solar system exploration alone is to pay 97% of the bill for the Shuttle even though robotic exploration of the solar system is one of the most relevant of science enterprises to human exploration.

This simply cannot be done without serious damage to an enterprise and community that should, and needs to be, a partner with human exploration.

NASA officials attempt to put positive spin on this damage by citing the growth of space science in NASA from about 21 percent of the budget in 1992 to 32 percent today. But, during that same time period space science has been carrying the agency exploration flag, and the agency has been rightly proud of the productivity of the Earth and space sciences. Missions such as Hubble, Mars Exploration Rovers and Cassini/Huygens are, as Administrator Griffin himself said, the "crown jewels" of NASA. Yet he has set NASA science on a declining course, not even keeping up with the projected growth in the rest of the agency over the next five years.

Does it make good business sense to damage the most productive enterprise in your portfolio to promote a poorly performing one that you firmly expect to terminate in five years?

The President wants to grow Federal investment in science

The President's arguments on the need to increase Federal support of the physical sciences are particularly true of NASA science. Space exploration is an enormous draw to young people. This Nation never saw such an increase in new science graduates than after the start of the Space Age in 1957. Now, at the start of the President's new Vision for Space Exploration, we are doing everything we can to turn off brilliant young earth and space scientists by pulling the rug out from their prospects for the future.

The FY07 budget proposal and the NRC's Solar System Decadal Report

The FY07 budget proposal does serious damage to the course set for the Nation's solar system exploration enterprise in the NRC's Solar System Decadal Report through its recommendations for research, technology and flight missions. This National Academy report establishes the scientific goals for robotic solar system exploration for the decade 2003-2012, the measurements at solar system destinations required to meet those science goals, and the flight missions necessary to travel to these destinations. The report also makes recommendations on the basic research and technology developments required to support those flight missions and to prepare for future missions beyond the next decade.

Depleting the Science Pool

NASA's earth and space science enterprise is not just about flight missions. It is foremost about science. Flight missions are the tools for conducting that science—for implementing scientific exploration of our solar system and beyond. Science flight missions are not furnished by the government to the science community; they are created by the science community. Scientists constantly generate new science questions from their research and from previous mission results. They then devise the measurements that need to be made in order to answer those questions. And finally they work with the engineers to create flight mission concepts to make those measurements at solar system destinations. These scientists are spread throughout the country, conducting their basic research in universities, research centers and NASA Centers. They are supported primarily by NASA research grants in what's known as Research and Analysis programs, or R&A, and by grants for mission data analysis also now covered in the R&A portion of the SMD budget.

While the 2003 Solar System Decadal Report recommends that R&A be increased over this decade at a rate above inflation, the FY07 budget would reduce funding for R&A by 15% across the board. For reasons hard to fathom, one particular program, Astrobiology, is targeted for a 50-percent reduction. Astrobiology was specifically named by the Decadal report as an important new component in the R&A program and is recognized even outside NASA as the agency's newest and most innovative research program bringing biologists, geologists and space scientists together to understand the earliest life on Earth and how we might search for life elsewhere beyond our own planet. The consequences of these unprecedented reductions would be to cripple the ability of NASA's science enterprise to create the next generation flight missions and worse of all it will short-circuit the careers of many young scientists. Precisely the opposite of what this country needs to remain competitive.

And all these cuts are immediate – today, in the 2006 budget year. Grants are to be reduced immediately, dimming the prospects of many young, motivated students now. What kind of message is that to the best and brightest of American's hopes for a rich technological future? And if there is to be any science at all in human space flight to the Moon and beyond, it needs to come from these young people.

Reducing Flight Missions

The Decadal Report also prioritizes the flight missions proposed for the next decade within separate cost categories—small, medium and large. For small missions, the report assumes a Discovery program of low cost, competed missions at a rate of about one launch per 18 months or about 6 per decade, and for the Discovery-like Mars Scouts about 3 launches per decade. Both of these assumptions are based on their historical annual budget levels.

For medium class missions, the report assumes a New Frontiers program of competed missions at a rate of about 3 per decade. This is the rate established for the New Frontiers line when it was opened with the Pluto/Kuiper Belt mission. For large, flagship missions, the report assumes 1 per decade based

on historical data for new starts in this category (Viking in the 1970s, Galileo in the 1980s, and Cassini- Huygens in the 1990s).

For the Mars Exploration flight program, the Decadal report assumed approximately two launches every 26 months, either two medium class launches or one medium and one small Mars Scout mission depending on timing and cost for the specific missions. This was based on the annual funding level for Mars Exploration in 2003.

The major damage in the FY07 budget to solar system flight missions is to the Mars and the Outer Planets flight programs. Mars flight missions are reduced from a nominal 2 launches per opportunity to only 1, and the number of medium missions is reduced by alternating launch opportunities between medium and small. Two Mars Scouts are eliminated, technology developments for missions beyond 2009 are reduced, and developments for a potential Mars Sample Return mission in the next decade practically eliminated. All of this will hobble our search for signs of past water and perhaps early life on our next-door neighbor.

For the Outer Planets flight program, the Europa Orbiter mission, only flagship mission and the highest science priority, is deferred to the next decade. For the first time in 4 decades there will be no solar system flagship mission at all. For science, we will remain ignorant that much longer of Europa's deep ocean and the potential for life within it. The Discovery program of small missions is already in prolonged delay and there will be no launch until the end of the decade, for a hiatus of more than four years since the last. And the third New Frontiers mission selection is delayed by about a year. The inevitable result of these delays and deletions is the potential loss of technological expertise to conduct these missions. Young scientists and engineers will be forced to look elsewhere for a more reliable, sustainable career path. It is not possible to retain the best of people if there is a lack of stability and a no clear sense of a strong future. You can't have world-class flight missions without world-class people.

Tossing Technology

For this reason, more than the flight mission delays themselves, a failure to continue to develop the technologies required for accomplishing future missions short circuits the future. Sustaining funding for technology development is the key to surviving hard times in flight mission development and guaranteeing a future. This budget does just the opposite.

Concern for the future

The bottom line is that the future of our Nation's solar system exploration enterprise has been mortgaged. The momentum of current mission development will carry it for about two years, and then the bottom begins to fall. We must sustain the science and technology that will afford us a new future when we get there two years from now. Consistent with the NRC Decadal study, the most important elements to sustain the enterprise are the fundamental research programs that form the basis for solar system exploration and the lowest cost, highest flight rate, widely competed flight programs in the small to medium flight mission lines. And if we are ever to recover, we must also invest in our technological readiness for flagship missions in the future.

Is this the best Vision?

The Vision is about robots and humans exploring to find our destiny in the solar system together. Instead of drawing on the strengths of both, this budget pits one vs. the other and undermines the Vision rather than promoting it. It pawns a planetary exploration program that is the envy of the world to pay for a program beset with problems and slated for termination.

The Administrator's budget message said about the Vision, "we will go as we can afford to pay." But the only way he can pay is by taking resources from the future of science and robotic exploration. If these annual reductions in NASA's budget continue, and if NASA continues to drain resources from science and technology, then America can retire as the leading nation in the scientific exploration of space, whether by robots or by humans.

Statement of
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and
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National Research Council
The National Academies

Before the
Committee on Science
The U.S. House of Representatives
Hearing on
NASA's Science Mission Directorate
Impacts of the Fiscal Year 2007 Budget Proposal

MARCH 2, 2006

Introduction

Mr. Chairman, Ranking Minority Member, and members of the committee: thank you for inviting me here to testify today. My name is Berrien Moore, and I am a professor of systems research at the University of New Hampshire and Director of the Institute for the Study of Earth, Oceans, and Space. I appear today largely in my capacity as co-chair of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space[1]. The views expressed in today's testimony are my own, but I believe they reflect community concerns. They are also fully supported by my co-chair for the NRC study, Dr. Richard Anthes, President of the University Corporation for Atmospheric Research (UCAR) and President-elect of the American Meteorological Society.

As you know, the NRC is the unit of the National Academies that is responsible for organizing independent advisory studies for the federal government on science and technology. In response to requests from NASA, NOAA, and the USGS, the National Research Council has begun a "decadal survey" of Earth science and applications from space which is due to be completed in late 2006. The guiding principle for the study, which was developed in consultation with members of the Earth science community, is to set an agenda for Earth science and applications from space, including everything from short-term needs for information, such as environmental warnings for protection of life and property, to longer-term scientific understanding that is essential for understanding our planet and is the lifeblood of future societal applications.

The NRC has been conducting decadal strategy surveys in astronomy for four decades, but it has only started to do them in other areas fairly recently. This is the first decadal survey in Earth science and applications from space.

Among the key tasks in the charge to the decadal survey committee is the request to:

- Develop a consensus of the top-level scientific questions that should provide the focus for Earth and environmental observations in the period 2005-2020; and
- Develop a prioritized list of recommended space programs, missions, and supporting activities to address these questions.

Recognizing the near-term challenges likely for FY2006 and FY2007, the sponsors of the decadal study requested an examination of urgent issues that required attention prior to publication of the survey committee's final report, which was scheduled for publication in the fall of 2006. The committee's "Interim Report," "Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation," was delivered to the sponsors and briefed to this Committee on 28 April 2005[2].

In the Interim Report, we stated that the nation's "system of environmental satellites is at risk of collapse." That statement, which may have seemed somewhat extreme at the time, was made before Hydros and Deep Space Climate Observatory missions were cancelled; before the Global Precipitation Mission was delayed for two and a half years; before the NPOESS Preparatory Program mission was delayed for a year and a half; before the NPOESS program breached the Nunn-McCurdy budget cap and was delayed for at least several years, and before significant cuts were made to NASA's Research and Analysis account. In less than a year since our Interim Report was issued, matters have gotten progressively worse.

It is against this backdrop that I turn to the Committee's questions.

What do you see as the most serious impacts on your field of the proposed slowed growth in the Science Mission Directorate? Clearly, it would be better to conduct more science than less, but what is the real harm in delaying specific missions? At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?

The most serious impacts on Earth Sciences of the proposed slowed growth in the Science Mission Directorate are the severe cuts in the Research and Analysis program. These cuts would be very damaging to the science and technology programs in the United States, particularly those at universities. We all know that our country is struggling to attract students to physics and mathematics. In the State of the Union address, President Bush proposed, "to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years." The President's proposal was part of a larger effort to "encourage children to take more math and science, and to make sure those courses are rigorous enough to compete with other nations." In my view, the cuts to NASA's Research and Analysis program in Earth Science are at odds with these objectives.

The numerous mission cancellations, deferrals, and de-scoping that have occurred in the previous 2 budget cycles have already had a severe detrimental effect on NASA Earth science. The table below, which is taken from the Interim Report, shows just the effects of the FY2006 budget[3]. I am concerned that the new cuts in the FY2007 budget, especially the significant reductions in funding for Research and Analysis, could have a devastating effect on a program already pared to the bone.

For example, it is my understanding that approximately half of the NASA Goddard Spaceflight Center's workforce is made up of contractors. The proposed cuts across NASA for Research and Analysis funding are approximately 15%. In the Earth sciences, I am told that the cuts for FY2007 appear to be closer to 20% in key elements. Since Goddard cannot reduce its civil service workforce, this cut will be magnified by a factor of 2 on the contractor workforce. The current contractor workforce is about 300 people and thus up to 120 people could be let go. A similar impact is likely at universities, especially as NASA will have to pay its civil servants first. Research and analysis grants will be cut; members of the community are concerned that grants already awarded might be withdrawn.

Because of the nature of the competitive process, universities, industry, and NASA centers must invest significant internal funds to prepare proposals that are compelling scientifically. Prematurely cutting missions or research awards for non-technical or cost reasons or eliminating grants after they have been awarded will have permanent, damaging consequences. The scientific community is beginning to question the reliability of NASA as a partner, and the wisdom of investing internal resources in the proposal development process.

Another impact is to reduce scientific research on missions that have already been launched and are providing novel observations of the Earth with unprecedented opportunities to learn about our planet. Cutting the research after all of the expense of building and launching the missions means that much of the up-front, and most expensive part of the mission will be wasted.

While I understand that NASA is facing difficult budgetary decisions, and priorities must be set, it would be a severe blow to NASA science to allow the R&A awards to be cut—especially given the already large investment in missions and the relatively low-cost, productive, and unique scientific understandings that result from these awards.

I shall return to this topic in answering your second question, but first let me address the other two components of the

Canceled, Descoped, or Delayed Earth Observation Missions (from the April 2005 Interim Report of the Decadal Survey)

Mission	Measurement	Societal Benefit	Status
Global Precipitation Measurement (GPM)	Precipitation	Reduced vulnerability to floods and droughts; improved capability to manage water resources in arid regions; improved forecasts of hurricanes	Delayed
Atmospheric Soundings from Geostationary Orbit (GIFTS—Geostationary Imaging Fourier Transform Spectrometer)	Temperature and water vapor	Protection of life and property through improved weather forecasts and severe storm warnings	Canceled
Ocean Vector Winds (active scatterometer follow-on to QuikSCAT)	Wind speed and direction near the ocean surface	Improved severe weather warnings to ships at sea; improved crop planning and yields through better predictions of El Niño	Canceled
Landsat Data Continuity—bridge mission (to fill gap between Landsat-7 and NPOESS)	Land cover	Monitoring of deforestation; identification of mineral resources; tracking of the conversion of agricultural land to other uses	Canceled
Glory	Optical properties of aerosols; solar irradiance	Improved scientific understanding of factors that force climate change	Canceled
Wide Swath Ocean Altimeter (on the Ocean Surface Topography Mission; OSTM)	Sea level in two dimensions	Monitoring of coastal currents, eddies, and tides, all of which affect fisheries, navigation, and ocean climate	Instrument canceled—descope of an enhanced OSTM

Committee's first question: the impact of mission delays and retaining or attracting scientists and engineers.

The impact of added delays are two-fold: 1) There will be increased costs downstream that will further undermine the possibilities for a revitalized future Earth science program, and 2) There will be continued negative impact on the morale of scientists within and outside of NASA. The importance of this impact should not be underestimated.

As this committee knows, procurement stretch-outs always increase overall program costs. Moreover, moving costs forward in time for current missions in development means that there is less "out-year" money for the future. Once again, we are mortgaging our future. In addition, delays often mean the penalties of missed synergies and gaps in observations associated with delay in execution.

For example, the 2-year delay in the Global Precipitation Mission (GPM) will create a gap between its operation and that of the Tropical Rainfall Measurement Mission (TRMM), whose science operations were extended last year in part because of their valuable role in meteorological forecasts of severe weather events. The delay of GPM also endangers a carefully planned partnership with the Japanese space agency, JAXA.[4] Goddard will also be challenged to maintain a viable mission given a flat funding profile for GPM from FY2006 through FY08. Project scientists are rightfully concerned that the 2-year delay in GPM threatens the viability of the mission.

However, I am equally concerned about the impact of program delays on the morale of scientists within and outside of NASA and the health of the specialized workforce that is necessary to maintain core competencies. From personal conversations and anecdotal reports, the sense of gloom and discouragement is widespread, and this is obviously connected to your important question, "At what point do delays or cutbacks become severe enough to make it difficult to retain or attract scientists or engineers to your field?" In my view, we are well past that point—the prior deterioration of the NASA Earth Science program, which was discussed in the Interim Report, has already had an adverse impact on our ability to attract scientists or engineers. This situation will only grow worse unless there are significant improvements to the FY2007 budget proposal.

Do you believe the decisions NASA has made concerning which missions to defer or cancel are consistent with the interim report of the National Academies Decadal Survey that you released? Given the FY2007 budget request, do you see any need to change the process for the next Decadal Survey?

The budget is inconsistent with the Interim Report. This is the real issue.

The Interim Report endorsed the Hydros Mission; subsequently but before the FY2007 budget was released, Hydros was cancelled. So was the Deep Space Climate Observatory, which was not addressed by the Interim Report, but had been supported by an earlier panel of the Academy.[5] The Interim Report stated that the Global Precipitation Mission should "proceed immediately and without further delay." The NASA FY2007 action delays the mission by two and a half years.

The Interim Report not only recommended that NASA and NOAA complete the fabrication, testing, and space qualification of the atmospheric soundings from geostationary orbit instrument (GIFTS--Geostationary Imaging Fourier Transform Spectrometer), but it also recommended that they support the international effort to launch this instrument by 2008. While NOAA has completed some of the space qualification of GIFTS, the FY2007 budget does not provide the additional funding that would be necessary to complete GIFTS.

The Interim Report also asked for studies regarding linking of NASA missions and plans and the NPOESS program in several key measurement areas: ocean vector winds, atmospheric aerosols, solar irradiance. We also requested an analysis of the capabilities of the then planned NPOESS Operational Land Imager (OLI) to execute the LandSat Data Continuity Mission. We have not received these studies, though we recognize that events subsequent to the publication of our report have altered the circumstances for some of the requests. However, I believe that the need for such studies has increased given the budget challenges for NASA and NOAA, the delay, cost growth, and likely changes to NPOESS, and the delay and changing ideas for the development of an operational land imaging capability and implementation of the LDCM.

The Interim Report called for the release of the next Announcement of Opportunity (AO) for the Earth System Science Pathfinder (ESSP) program in FY 2005; we understand that the earliest AO for the next ESSP will be FY 2008.

Finally, in closing my April 2005 testimony before this Committee**,** I stated that the Decadal Survey Committee was "concerned about diminished resources for the research and analysis (R&A) programs that sustain the interpretation of Earth science data. Because the R&A programs are carried out largely through the Nation's research universities, there will be an immediate and deleterious impact on graduate student, postdoctoral, and faculty research support. The long-term consequence will be a diminished ability to attract and retain students interested in using and developing Earth observations. Taken together, these developments jeopardize U.S. leadership in both Earth science and Earth observations, and they undermine the vitality of the government-university-private sector partnership that has made so many contributions to society." Unfortunately, the FY2007 budget for Earth Science reflects cuts of 15% or more in the overall R&A program for Earth Science. We are headed in the wrong direction.

How should NASA balance priorities among the various disciplines supported by its Science Mission Directorate? Do you believe the proposed FY2007 budget, given the overall level of spending allotted to science, does a good job of setting priorities across fields?

As noted above, NASA's science programs have already sustained deep cuts in the last two budget cycles. Exacerbating the cuts is the recent and not widely reported downward modifications to the Operating Plan for FY2006. These cuts, which were submitted shortly after the release of the FY2007 budget, make the proposed FY2007 budget cuts retroactive to the beginning of FY2006. The timing of the cuts makes their effect more severe; it also masks the magnitude of what is an enormous cut to the FY2007 budget (because the comparison of FY07 to FY06 is now made with new, reduced FY2006). Budget analyses that do not account for these recent changes leave the impression that the NASA Earth Science research budget is flat when in fact it has been decimated.

In response to the committee's question above: Budget priorities at NASA must be balanced to reflect the highest priorities of the four decadal surveys. The scientific community recognizes that much will not be accomplished in our current budget environment, but we must seek to realize the highest priority elements. I strongly support the FY2006 Authorizing language charging the NASA Administrator "to develop a plan to guide the science programs of NASA through 2016."

Let me conclude my testimony by stating my strong support, which I did publicly at the December 2005 meeting of the AGU, for the new leadership at NASA. I believe that the science community as a whole is also strongly supportive of the new leadership. However, NASA is now being directed to do more than is possible with the resources it has been given. I believe the health of science programs at NASA, which less than 3 months ago were said to be protected by a "firewall" from obligations to complete the ISS, develop the CEV, and return the Shuttle to flight, is in peril. Simply stated, given the NASA "bottom line" budget number and the "demands" of Station, Shuttle, and Exploration, there is far less room ($3.1 billion less in the next 5 years) for science.

Further, one can be reasonably sure that the pressure on science to fund under-budgeted parts of NASA flight programs will only increase—few, if any, large and complex technology development projects come in under budget. While not the subject of this hearing, this situation begs for an honest appraisal of NASA's portfolio, its priorities, and whether the Nation can afford to allow NASA science programs to languish.

I look forward to answering any questions you may have. Thank you.

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[1] <http://qp.nas.edu/decadalsurvey>

[2] National Research Council, *Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*, The National Academies Press, 2005. < http://www.nap.edu/catalog/11281.html>.

[3] Ibid, page 17. Note that the Glory mission was subsequently restored. The latest plan for LDCM is to implement the mission as a free-flyer with a launch in 2011.

[4] Among other items, JAXA is developing the dual-frequency precipitation radar that is at the heart of the GPM mission.

[5] National Research Council, *Review of Scientific Aspects of the NASA Triana Mission: Letter Report*, National Academies Press, 2000. <http://www.nap.edu/catalog/9789.html>.

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Distributed Arrays of Small Instruments for Solar Terrestrial Research: Report of a Workshop

This report by the Ad hoc Committee on Distributed Arrays of Small Instruments for Research and Monitoring in Solar-Terrestrial Physics: A Workshop is available in prepublication format online at http://fermat.nap.edu/catalog/11594.html. The study was staffed by Arthur Charo, Study Director, Angela Baber, Research Assistant, Catherine Gruber, Assistant Editor, and Theresa Fisher, Senior Project Assistant). The following is adapted from the executive summary of the report.

EXECUTIVE SUMMARY

To explore the scientific rationale for arrays of small instruments recommended in the 2002 NRC decadal survey for solar and space physics, the infrastructure needed to support and utilize such arrays, and proposals for an implementation plan for their deployment, an ad hoc committee established under the Space Studies Board's Committee on Solar and Space Physics organized the 1.5-day Workshop on Distributed Arrays of Small Instruments held in June 2004 at the National Academies' Jonnson Center in Woods Hole, Massachusetts. This report summarizes the discussions at the workshop; it does not present findings or recommendations.

Solar-terrestrial science addresses a coupled system extending from the Sun and heliosphere to Earth's outer magnetosphere and ionosphere to the lower layers of the atmosphere, which are connected via the thermosphere and lower ionosphere. Processes in each region can affect those in the other regions through coupling and feedback mechanisms. As the 2002 decadal survey and other related NRC reports have noted, understanding and monitoring the fundamental processes responsible for solar-terrestrial coupling are vital to being able to fully explain the influence of the Sun on the near-Earth environment. These studies emphasize that monitoring the spatial and temporal development of global current systems and flows; the energization and loss of energetic particles; and the transport of mass, energy, and momentum throughout the magnetosphere and coupled layers of Earth's upper atmosphere is essential to achieving this scientific goal.

At the workshop, speakers asserted that deployment of distributed arrays of small instruments (DASI) would culminate decades of discipline-related local instrument development for the pursuit of aspects of solar-terrestrial science at the subsystem level. With the advent of the Internet and affordable high-speed computing, these local deployments can now become elements of a global instrument system. When different instrument techniques are then combined to observe all aspects of the physical system, the DASI concept will be realized.

Proponents of the DASI concept emphasized that DASI's strength is that it offers a cost-effective means of performing original and critically important science, with a development strategy that allows DASI's progress to enable and flow into future initiatives. DASI will complement and extend the capabilities of the next generation of space-based research and space weather instruments by providing a global context within which to understand in situ and remote sensing observations.

During the course of the workshop, three recurrent themes became evident: (1) the need to address geospace as a system, (2) the need for real-time observations, and (3) the insufficiency of current observations.

1. *Geospace as a system*—Understanding the Sun's influence on Earth's global space environment requires detailed knowledge of the atmosphere-ionosphere-magnetosphere system. This extremely complex natural system involves many different interacting elements, and Earth is the only planetary system that scientists can expect to study in detail. Today, the science of space plasma physics has matured to the level of being able both to describe many of these interactions and to model them. A major goal in solar-terrestrial science now is to unify scientific understanding so as to achieve a more comprehensive computational framework that will enable prediction of the properties of this system¾conditions known as space weather that affect Earth and its technological systems. To do this accurately, however, requires an understanding of Earth's global behavior as it exists, rather than as it occurs in an idealized representation. Realizing such goals requires the assimilation and integration of data from disparate sources.

2. *The need for real-time observations*—The magnetosphere-ionosphere-thermosphere (M-I-T) system is a highly dynamic, nonlinear system that can vary significantly from hour to hour at any location. The coupling is particularly strong during geomagnetic storms and substorms, but there are appreciable time delays associated with the transfer of mass, momentum, and energy between the different domains. Also, it is now becoming clear that a significant fraction of the flow of mass, momentum, and energy in the M-I-T system occurs on relatively small spatial scales and over a wide range of temporal scales. Consequently, elucidation of the fundamental coupling processes requires continuous, coordinated, real-time measurements from a distributed array of diverse instruments, as well as physics-based data assimilation models.

3. *Insufficiency of current observations*—Observational space physics is data-starved, leading to large gaps in the ability to both characterize and understand important phenomena. This is particularly true for space weather events, which often are fast-developing and dynamic and which extend well beyond the normal spatial coverage of current (ground-based or space) sensor arrays.

Issues addressed in presentations and breakout session discussions at the workshop can be summarized in a number of fundamental science questions reflecting what participants saw as opportunities for the DASI concept to contribute to progress in understanding the Sun's influence on the near-Earth environment. They included the following:

- What is the configuration of the magnetosphere-ionosphere-thermosphere system that is most vulnerable to space weather?
- What are the processes and effects associated with plasma redistribution during disturbed conditions?
- What is the role of the ionosphere-thermosphere system in the processes associated with particle energization?
- What are the effects of preconditioning in the ionosphere and magnetosphere on the evolution of disturbances?
- What processes affect ion-neutral coupling in the presence of particle precipitation?
- What are the causes of thermosphere-ionosphere variability during geomagnetically quiescent periods?
- What are the structure and dynamics of the Sun's interior?
- What are the causes of solar activity?
- How does the structure of the heliosphere modify the solar wind?
- Can low-frequency interplanetary scintillations be used to make global determinations of solar wind velocity?

Among the major ground-based remote sensing instruments described by workshop participants were the following:

- Very-low-frequency and high-frequency receivers and radio telescopes;
- High- and medium-power active radars and low-power passive radars;
- Ionosondes;
- Magnetometers;
- Passive and active optical instruments (interferometers, spectrometers, lidars); and
- Solar imagers, spectrographs, polimeters, magnetographs, and radio telescopes.

Speakers also noted the importance of computer models that are capable of assimilating the observations.

Attention at the workshop sessions was also devoted to issues regarding the infrastructure needs for future distributed arrays of ground-based instruments. Information technology was especially emphasized. Speakers cited the Virtual Observatory model that is being used in the solar and astronomy communities as an excellent starting point and template for DASI. Other information technology capabilities of note included the use of Internet and computer grid technology and high-data-rate, near-real-time communications systems. Finally, the workshop illuminated logistics considerations for the DASI concept, including key instrument spacing and size requirements for some classes of instruments as well as opportunities for and constraints on instrument placement in key scientific locations.

Throughout the workshop participants discussed a number of areas in which the space research community can begin an organized effort to develop a coordinated space-research instrumentation system. Although no consensus on priorities was sought or attempted, participants identified the following near-term actions as means to further evaluate the potential of the DASI concept and to prepare for its future development and implementation:

- Hold community workshops to address in greater detail the instrumentation, science, and deployment issues associated with DASI.
- Identify areas in which existing and planned instrument arrays and clusters can share technology, data distribution architectures, and logistics experience.
- Consolidate currently planned systems to form a regional implementation of next-generation coordinated instrument arrays.
- Establish closer connections with other research communities that are developing similar distributed instrumentation systems.
- Coordinate efforts in the U.S. community with similar international efforts.
- Move toward developing rugged, miniaturized instruments, using a common data format.
- Support efforts to establish common data communication technologies and protocols.
- Work with agency sponsors to begin a phased implementation of the DASI program.

Achieving the science objectives for DASI will require a global deployment of instruments and a large commitment of resources. Although the workshop did not go into detail on the areas of collaboration or opportunities to be pursued, participants felt strongly that international collaboration should be a fundamental part of the DASI plan.

Assessment of Planetary Protection Requirements for Venus Missions

On February 8, 2006, Task Group Chair, Jack W. Szostak, sent a letter report to Dr. John D. Rummel, NASA's Planetary Protection Officer . The letter report is available online in PDF format at http://fermat.nap.edu/catalog/11584.html. The study was staffed by David H. Smith, Study Director, Catherine Gruber, Assistant Editor, and Rodney N. Howard, Senior Program Assistant.

The transmittal letter to Dr. John D. Rummel follows:

As originally written in your letter of February 7, 2005, to Space Studies Board (SSB) Chair Lennard Fisk and reiterated at the February 9-11, 2005, meeting of the SSB's Committee on the Origin and Evolution of Life (COEL), you asked for advice on planetary protection concerns related to missions to and from Venus. In particular, you asked that the National Research Council (NRC) address three issues in terms of their implications for planetary protection:

1. Assess the surface and atmospheric environments of Venus with respect to their ability to support Earth-origin microbial contamination, and recommend measures, if any, that should be taken to prevent the forward contamination of Venus by future spacecraft missions;
2. Provide recommendations related to planetary protection issues associated with the return to Earth of samples from Venus; and
3. Identify scientific investigations that may be required to reduce uncertainty in the above assessments.

In response to your request, the Task Group on Planetary Protection Requirements for Venus Missions was formed (the membership of the task group is listed in Attachment 1) and met at the Southwest Research Institute in Boulder, Colorado, on October 3-5, 2005. The task group's deliberations and discussions relating to the conclusions and recommendations contained in this letter report were confined to the Boulder meeting. To set the context for and define the scope of this study, presentations were given and discussions were held at two meetings of COEL earlier in 2005—the February 9-11 and May 31-June 2 meetings at the National Academies' Keck Center in Washington, DC, and its Jonsson Center in Woods Hole, Massachusetts, respectively. These preliminary presentations and discussions were conducted under the aegis of COEL's standing oversight of NASA's Astrobiology program and in its role as the organizing committee for the SSB's astrobiological activities. And, since all but two members of the task group are also members of COEL, the majority of the authoring group of this letter report participated in all three meetings and heard the following presentations relevant to this study:

- *At the meeting in Washington, DC,* you briefed the committee on the topic "Planetary Protection Classification of Venus," and Dirk Schulze-Makuch (Washington State University) spoke on the question "A Case for Life on Venus?"
- *At the meeting in Woods Hole, Massachusetts,* you presented an updated version of "Planetary Protection Classification of Venus," and Linda Amaral Zettler (Marine Biological Laboratory) addressed the topic "Acidophiles in the Rio Tinto." In addition, Martha Gilmore (Wesleyan University) and James W. Head III (Brown University) gave presentations respectively entitled "NASA Planning for Venus Sample-Return Missions" and "Origin and Evolution of Venus's Environment."
- *At the meeting in Boulder, Colorado,* D. Kirk Nordstrom (U.S. Geological Survey) gave a talk titled "Negative pH, Efflorescent Mineralogy and Consequences for Environmental Restoration at Iron Mountain." Mark Bullock (Southwest Research Institute) gave the presentation "Origin and Evolution of Venus's Environment," and task group member David Grinspoon gave the summary presentation entitled "The Astrobiology of Venus." In addition, individual task group members held extensive discussions in open and closed sessions.

The task group consulted related reports issued by the SSB and other NRC committees (e.g., *Recommendations on Quarantine Policy for Mars, Jupiter, Saturn, Uranus, Neptune, and Titan [1978], An Integrated Strategy for the Planetary Sciences: 1995-2010* [1994], *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies* [1998], *A Science Strategy for the Exploration of Europa* [1999], and *Preventing the Forward Contamination of Europa* [2000]).

In its deliberations, the task group examined planetary protection considerations affecting Venus missions. The known aspects of the present-day environment of Venus offer compelling arguments against there being significant dangers of forward or reverse biological contamination, regardless of the unknowns. Full details are contained in the attached "Assessment of Planetary Protection Requirements for Venus Missions."

Because of the extreme temperature at the Venus surface, the fact that concentrated H_2SO_4 is sterilizing for all known Earth organisms, the consideration that the Venus cloud environment is extremely dehydrating and oxidizing, and the realization that any life forms adapted to the Venus clouds would not survive in Earth conditions, **with respect to planetary protection issues, the task group concluded as follows:**

- **No significant risk of forward contamination exists in landing on the surface of Venus;**
- **No significant forward-contamination risk exists regarding the exposure of spacecraft to the clouds in the atmosphere of Venus;**
- **No significant back-contamination risk exists concerning the return of atmospheric samples from the clouds in the atmosphere of Venus; and**
- **No significant risk exists concerning back contamination from Venus surface sample returns.**

Currently, NASA classifies Venus missions under planetary protection Category II, which "includes all types of missions to target those bodies where there is significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote chance that contamination carried by a spacecraft could jeopardize future exploration," rather than under the less restrictive Category I assigned by the Committee on Space Research (COSPAR) of the International Council for Science. **The task group recommends that the Category II planetary protection classification of Venus be retained.** Although there are many important scientific investigations to be carried out to improve understanding and knowledge of Venus, **the task**

group does not recommend any scientific investigations for the specific purpose of reducing uncertainty with respect to planetary protection issues. The considerations that led to the above conclusions are presented in the attached assessment.

Sincerely,
Jack W. Szostak, *Chair*

STAFF NEWS

After almost ten years of service at the National Academies, ***Dr. Tamara L. Dickinson*** has moved on to the Policy Program at the American Meteorological Society as a senior policy fellow and director of the Policy Studies Series. During most of her tenure at the Academies, Tammy served as study director of the Committee on Earth Resource in the Board on Earth Sciences and Resources for eight years. She most recently served as the associate board director and the interim board director of the SSB, where she was instrumental in guiding the board during its recent transition. While we are sad to see her leave the Academies, we wish Tammy much luck in her future endeavors.

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10-12	COMMITTEE ON THE ASTROBIOLOGY STRATEGY FOR THE EXPLORATION OF MARS	WASHINGTON, DC
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NOVEMBER		
8-10	COMMITTEE ON THE ORIGINS AND EVOLUTION OF LIFE	TBD
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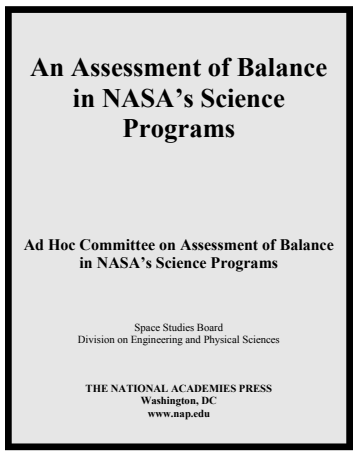

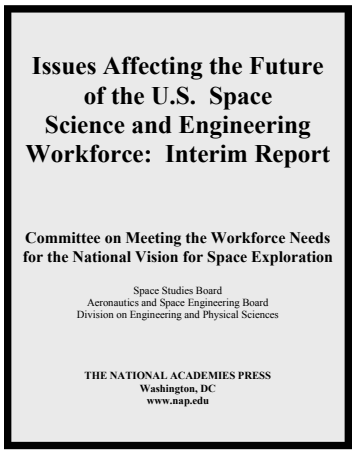

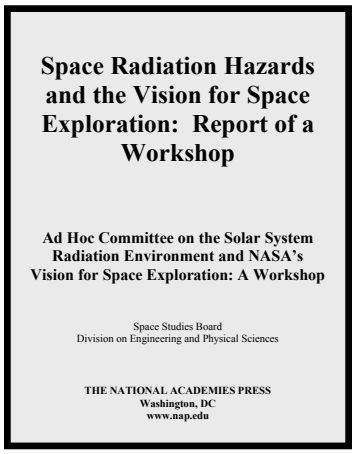

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