SPACE STUDIES BOARD NEWS

OCTOBER—DECEMBER 2006

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Beyond Einstein Program Assessment Committee—**Newport Beach, CA**	*Jan. 30-Feb. 1*
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Lunar Science Strategy Committee—**Boulder, CO**	*Feb. 13-15*
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Beyond Einstein Program Assessment Committee Town Hall Meeting—**Baltimore, MD**	*Mar. 14*
COSPAR Program and Bureau Meetings—**Paris, France**	*Mar. 19-22*

FROM THE CHAIR

It is time again, at the beginning of a New Year, to pause and reflect on the year past and to anticipate the year ahead. Our pause this year is almost a necessity since there is great uncertainty about the health and the near-term future of the space program. Congress went home without passing a FY2007 appropriations bill for NASA, the fiscal year we are now three months into. The new Congress is threatening to leave NASA at the FY2006 funding level. (See the Director's column for more details.) It is uncertain, then, whether the painful cuts to science, and particularly to the Research & Analysis program, will be redressed, or exasperated. It is unlikely that the Mikulski-Hutchison amendment to rescue NASA from wholly inadequate funding to accomplish its mission can succeed.

It is also too early for the President's FY2008 budget for NASA, due to be released in early February. We are entering into the last two years of the current administration, which is preoccupied with the war in Iraq and the legacy of this President. NASA, which is attempting to make visible progress on the President's Vision for Space Exploration to the Moon and beyond, could prosper, or be caught in the downdraft of a diminished administration.

There is also uncertainty in the science leadership of NASA. Mary Cleave, the Associate Administrator for the Science Mission Directorship, has announced that she will retire in March, and, at least at the time of the writing of this column, her replacement has not been named. This individual will have profound influence on the future of space and Earth science, provided of course that he or she is granted the authority to lead.

We have new Congressional leadership, with the Democrats taking over the chairs of all Congressional committees. NASA has been fortunate to have bipartisan support, and so its support should not diminish. However, there is a clear intent by the new leadership to hold the current administration accountable for all its actions, and NASA should not expect to be an exception.

As we mull over last year, in our period of reflection, several highlights come to mind. NASA, to its credit, got the Shuttle flying regularly again and made considerable progress on the completion of the International Space Station. Unfortunately, the mere act of bringing the Station closer to completion exposed the fact that the U.S. has few, if any, plans to use it, with many experiments having been canceled and many researchers driven from the field of life and physical sciences in microgravity.

There was the usual number of exciting scientific discoveries, showing the continual vibrancy of the space and Earth science program. Gratifying also was the awarding of the Nobel Prize in Physics to John Mather and George Smoot for their discoveries with the COBE mission. Not unnoticed was the fact that COBE was an Explorer mission, a program that has been decimated since the initiation of the Vision for Space Exploration.

NASA made progress in replacing the Shuttle by taking necessary steps to develop the Crew Exploration Vehicle, Orion, and its launch vehicle, Ares. NASA ended the year by announcing the results of a massive effort to collect ideas on what to do on the Moon, and concluded that a lunar base was appropriate. It is heartening to know that there is much to do on the Moon, but discouraging that most of it is beyond the financial resources that are likely to be available, or even beyond the career lifetimes of all but the youngest of scientists or engineers. Indeed, the cited reasons to go to the moon and the opportunities to pursue are so massive that it is hard to imagine that they could be used to set reasonable priorities. Surely, NASA is not repeating the mistakes of the early Space Station era in which too much was promised to too many.

And then there was the saga of the NASA internal advisory structure. The scientific community objected to the internal advisory structure imposed by the NASA Administrator, in

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which all advice is channeled through the NASA Advisory Council (NAC). Two members of the NAC were fired and another resigned rather than be fired, in large part for objecting to the new structure, and they were replaced. Setting aside all of the rhetoric and passion associated with this event and its aftermath, we can ask the simple question—is the new structure functional? At the level of the Science Subcommittees, which interact with the division directors, it does appear to work for the simple reason that the division directors receive the advice directly. The Associate Administrator for Science, however, has no way to get advice or seek support from the community, since all her advice has to flow from the NAC's Science Committee to the full NAC to the Administrator and back down. And along the way there are lawyers. In October, the NAC Science Committee actually passed a resolution of substance and forwarded it to the NAC, only to be told that its advice was tainted by a conflict of interest and therefore unacceptable. The Federal Advisory Committee Act (FACA), which governs advisory committees such as the NAC, was passed in 1972 and amended several times in the 1990s. How strange that NASA functioned for all those years, with a vibrant internal advisory structure rendering advice at all levels of the science program, but now cannot.

The coming year portends to be a most interesting and important one. The NRC decadal survey for Earth science was be released on January 15, 2007. This is a long-awaited document. For more than a decade now the Earth science program has been atrophying, and in recent years it has been practically in freefall. The decadal survey is the roadmap out of the abyss. There is a growing national sentiment to move more aggressively on understanding the environment and to make wise policy decisions to protect our future. NASA has a major role here, but not the resources required. Will NASA be provided with the resources, or will the broader science program be asked to take one for the team again? Or will this opportunity to revitalize the Earth science program of NASA be lost?

One indication of whether Earth science in NASA will rebound will come from the upcoming Presidential election in 2008. It is early in the campaign, and there are only a few candidates openly declared, but many more likely. There is a sense that global climate change, and the anemic response of the current Administration, will be a campaign issue. Certainly not at the same level of concern as Iraq, but nonetheless of much more visibility than ever before. NASA Earth science could do well in a belated response from the current Administration, and even more so in the next Administration, regardless of party.

And since we are speculating on the year ahead, why not speculate with optimism that someone in a leadership position will move aggressively to fix the things that are broken in space and Earth sciences. Perhaps we should make a list and pass it in to the new Associate Administrator. Space missions cost too much. Something has gone seriously wrong, worldwide, with the management of flight programs. We are not getting full value for the funds spent, which in times of limited funding is a serious grievance. The scientific infrastructure of the nation is atrophying. University research groups, particularly experimental groups, are in decline. The science at NASA centers is being diminished by bureaucratic overload and seemingly simple things like inadequate accounting. An agency that argues that its best days lie ahead when it leads the civilization into space is seemingly unconcerned with the workforce and the infrastructure necessary for its success. The handoff to the next generation must be a managed process; new technology must be nurtured. And above all, the excitement of scientific discovery must always be encouraged. We are often awash in discouraging news about the constraints that funding and politics impose on us and can lose sight of the excitement of the science. The role of leadership in NASA should be to insulate the science practioners from these problems and encourage their success.

The space and Earth science program effectively began with the International Geophysical Year in 1957, with Sputnik, the formation of NASA, a host of scientific discoveries, and the launching of a generation of inspired scientists. In September of 2007, the National Academies will begin a yearlong series of events marking the 50th anniversary of the IGY; the final event in September 2008 will mark the 50th anniversary of the establishment of the Space Science Board [now renamed the Space Studies Board]. These events are not to be a celebration of the distant past, but rather a celebration of the excitement of the present and the promise of the future as the wonders of space open before us.

Lennard A. Fisk
lafisk@umich.edu

DIRECTOR'S CORNER

On January 12, George Levin, Director of the Aeronautics and Space Engineering Board (ASEB), retired from the NRC. George led the ASEB for almost 10 years, following a 35-year career at NASA. On behalf of everyone at the Space Studies Board, I want to wish George well in this second retirement. I know he plans to remain professionally active, so this still is not "real" retirement, and I'm certain that our paths will continue to cross.

The National Research Council, of which SSB and ASEB are part, asked me to serve as George's successor at ASEB, in addition to my duties as Director of SSB. There are obvious synergies between the two Boards, and having one person manage both makes sense. For example, NASA is the dominant sponsor of studies by both Boards, and the combined portfolio covers all of NASA's programmatic activities—space science, exploration systems, space operations, and aeronautics. We already do a number of joint studies, such as the ongoing study on Meeting the Workforce Needs for the National Vision for Space Exploration, and the 2005 study on Priorities in Space Science Enabled by Nuclear Power and Propulsion.

I am very much looking forward to working with ASEB chair Ray Colladay and the other members of the ASEB. The SSB and ASEB will remain separate boards, each with its own staff, but the staffs will be working very closely together.

The NRC thus is well positioned to provide advice to NASA and other sponsors about the space program and aeronautics research

in the years ahead.

What 2007 will bring to NASA and the Boards' other federal sponsors, however, is less certain. The prospect of a year-long continuing resolution (CR) to fund most of the federal government is unsettling. According to an internal NASA memo posted on NASAWatch (www.nasawatch.com), congressional staff advised NASA officials that NASA would be funded at $16.273 billion during FY2007, instead of the $16.792 billion the agency had requested, a reduction of about $530 million.

Some find solace in the fact that there would be no earmarks—congressionally directed spending that often must be absorbed by the agency within its requested budget level. However, some of those earmarks were for NASA programs championed by space scientists. Only about half of the $500 million in earmarks in NASA's FY2006 budget was for "site specific projects" directed to a particular congressional district or state. The other half was for NASA programs or projects that Congress deemed were not sufficiently supported in the President's budget request—an additional $80 million for the Hubble servicing mission, and $30 million to reinstate the Glory earth sciences mission, for example.

Similarly, without passage of a FY2007 appropriations bill for NASA, the space science community will lose earmarks that were included in the House-passed bill or the one reported from the Senate Appropriations Committee. The House added $50 million for research and analysis, $15 million for a Europa mission, and $10 million for the Terrestrial Planet Finder. The Mikulski-Hutchinson amendment in the Senate bill to add $1 billion to NASA to compensate for the return-to-flight costs of the space shuttle has also disappeared. A staffer for Senator Mikulski was quoted by *Space News* as saying that the amendment is now off the table.

Where does that leave NASA? The internal NASA memo posted on NASAWatch tells the tale. The majority of the $530 million shortfall would come from the Exploration Systems Mission Directorate, which is primarily responsible for executing the Vision for Space Exploration. The 4-year gap between the end of the space shuttle program and the availability of the new Orion Crew Exploration Vehicle could lengthen, and investments in the Lunar Robotic Precursor Program and Advanced Technology Development would be threatened. According to the memo, NASA "expects to adjust priorities within the Science, Aeronautics and Exploration appropriations accounts to manage the impact."

Short of convincing the new Congress to change its mind and pass the remaining appropriations bills that the last Congress was unable to finalize, there appears to be no good news ahead for NASA and most other agencies. (Only the appropriations bills for the Department of Defense and Department of Homeland Security have been enacted for FY2007.) The American Competitiveness Initiative announced by President Bush in his 2006 State of the Union address would be unfunded, to the dismay of NSF, DOE's Office of Science, and NIST. NSF would suffer further because FY2007 was supposed to be the first step in doubling the NSF budget over 10 years. NOAA would be impacted as well. The Dec. 14, 2006 issue of the American Institute of Physics (AIP) Bulletin cited NOAA's budget director as saying that a CR that lasted beyond February could lead to layoffs for 400 full-time employees and 400 full-time contractors.

Congress could change its mind and pass the remaining FY2007 bills and give NASA, for example, at least the amount it requested. While that seems unlikely as this newsletter goes to press, it is not impossible. Also, according to the NASA memo, the agency is investigating alternative methods of calculating how much NASA could get in FY2007 based on the CR, and congressional staff reportedly indicated to NASA that certain exceptions could be made.

The clear message, though, is that the budget situation for NASA probably is not going to improve in the near future. The SSB's ad hoc Committee on an Assessment of Balance in NASA's Science Program found in its May 2005 report that "NASA is being asked to accomplish too much with too little." Now the agency may have even less. The ad hoc committee's recommendation bears repeating: "Both the executive and the legislative branches of the federal government need to seriously examine the mismatch between the tasks assigned to NASA and the resources that the agency has been provided to accomplish them and should identify actions that will make the agency's portfolio of responsibilities sustainable."

Marcia S. Smith
msmith@nas.edu

BOARD AND COMMITTEE NEWS

THE BOARD AND ITS STANDING COMMITTEES

- The **Space Studies Board (SSB)** held a half day meeting at the National Academies' Beckman Center in Irvine, CA, on November 14, 2006. The Board meeting was followed by a two-day Board-sponsored workshop on decadal surveys, discussed elsewhere in this newsletter. The Board welcomed seven new members who joined in July: Steven Battel, Battel Engineering; Charles Bennett, Johns Hopkins University; Jack Fellows, UCAR; Kenneth Nealson, University of Southern California; James Pawelczyk, Pennsylvania State University; Joseph Veverka, Cornell University, and Warren Washington, NCAR. The annual balance and composition discussion was held.

The Board chair and vice-chair reported on discussions held at the Board's Executive Committee meeting in August 2006. Board members were presented with the executive summaries of four recently released SSB reports. In addition, the statements of task for three new or potential SSB activities were reviewed: *Earth Science and Applications from Space: Ensuring the Climate Measurements from NPOESS; NASA's Beyond Einstein Program: An Architecture for Implementation;* and a potential seminar series on *Celebrating the First 50 Years of Space Science: In Commemoration of the 50th Anniversary of the International Geophysical Year.*

The Board ended the meeting with a brief discussion of the objectives for the SSB Workshop on Decadal Surveys. The next meeting of the Board will be March 5-7, 2007, in Washington, DC.

- The **Committee on Astronomy and Astrophysics** (**CAA)** which operates under the joint auspices of the SSB and the Board on Physics and Astronomy met at the National Academies' Beckman Center in Irvine, CA, on November 28-29. The committee heard from Robin Staffin (DOE), Wayne Van Citters (NSF), Rick Howard (NASA), and Todd Boroson (NOAO) among others. The CAA will convene a Decadal Survey Town Hall on Tuesday, January 9, 2007, at the American Astronomical Society (AAS) meeting in Seattle, Washington. With this session, the BPA/SSB/CAA will begin a dialogue with the community about the next survey. The CAA is considering whether, in light of the current circumstances in the field, to recommend some adjustments in the decadal survey process. AAS members will be encouraged to take the opportunity presented by this Town Hall to comment on this issue. The next CAA meeting is scheduled to occur in May 2007.
- The **Committee on Earth Studies (CES)** continues to stand down as work continues on the decadal study.
- The **Committee on the Origins and Evolution of Life (COEL)** which operates under the joint auspices of the SSB and the Board on Life Sciences did not meet during this quarter. The next meeting of COEL will be held at the National Academies' Keck Center in Washington, DC, on February 19-21, 2007. The principal issues on the committee's agenda for 2007 are the appointment of approximately six new members to replace those whose terms ended in 2006 and the initiation of a possible project to review the achievement of, and to assess the future prospects for, the NASA Astrobiology Institute.
- The **Committee on Planetary and Lunar Exploration (COMPLEX)** held its final meeting of 2006 at the National Academies' Beckman Center in Irvine, CA, on December 4-6. This meeting was notable because it was the first to be presided over by COMPLEX's new chair, Joseph F. Veverka. Eight new committee members were also present at the meeting and two additional new members were, unfortunately, unable to attend. The principal item on the committee's agenda is the identification of potential new study projects. One item explored in detail at the December meeting is the possibility of a study to assess the candidates for future flagship and New Frontiers missions to explore objects in the outer solar system. The next meeting of COMPLEX will take place at the National Academies' Keck Center in Washington, DC, April 11-13, 2007.
- The **Committee on Solar and Space Physics (CSSP)** met October 11-13 at the National Academies' Keck Center in Washington, DC. The meeting focused on NASA, NSF, and NOAA programs and plans. From discussions with NASA officials, the committee learned of several new missions in development with launch dates extending up to about 2013; thereafter, the program plan is less clear. NASA's Science Mission Directorate—and Heliophysics, in particular—is working aggressively to identify Lunar Science opportunities in the Vision for Space Exploration. The committee also learned that NOAA has particular current concerns about space weather monitoring programs. Steve Mango of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO) described the recent changes to the NPOESS climate and space weather payload elements, which committee members characterized as "devastating." The committee also discussed plans for a workshop on the social and economic effects of severe space weather events.

STUDY COMMITTEES

- The **ad hoc Committee on the Astrobiology Strategy for the Exploration of Mars** held its final scheduled meeting at the National Academies' Jonsson Center in Woods Hole, MA, on November 8-10. The meeting was devoted to completing the committee's draft report, *An Astrobiology Strategy for the Exploration of Mars*. Following a committee conference call on December 7, a complete draft of the report was assembled and distributed to members on December 15. After review by committee members, the draft report was sent to eight external reviewers on December 19. Comments are due back in mid January and public release is expected by the end of March 2007.
- The **ad hoc Committee on Astronomy Science Centers** continued to complete responses to external reviews of its draft report. A final published report is being planned for release in late March 2007.
- The **ad hoc Beyond Einstein Program Assessment Committee** held its first meeting in Washington, DC, November 6-8. Representatives of the 11 Beyond Einstein mission concepts presented their projects and responded to committee questions. The next meeting is scheduled for January 30-February 1, 2007 at The Island Hotel in Newport Beach, CA; this meeting will include a Town Hall session on February 1.
- In late 2004, at the request of NASA (Earth Science), NOAA (NESDIS), and USGS (Geography), the SSB began a decadal survey, "**Earth Science and Applications from Space (ESAS): A Community Assessment and Strategy for the Future."** A key element of this study is the request to present consensus recommendations from the Earth science community regarding a systems approach to the space-based and ancillary observations that

encompass the research programs of NASA and the related operational programs of NOAA and the USGS. An interim report from the survey was published in April 2005. A pre-publication version of the final report was released on January 15, 2007. The report is available for download at: http://www.nap.edu/catalog/11820.html. The survey committee has also received a request to undertake a fast-track study that will examine strategies to recover lost capabilities stemming from the June 2006 changes to the NPOESS program. This study will also examine several issues related to recent changes in the GOES-R program.

- The **ad hoc Committee on the Limits of Organic Life in Planetary Systems** continued to complete responses to external reviews of its draft report. The committee plans to complete the report for release by March 31, 2007.
- The **ad hoc Committee on Meeting the Workforce Needs for the National Vision for Space Exploration,** which operates under the joint auspices of the SSB and the Aeronautics and Space Engineering Board, held its fourth meeting at the National Academies' Beckman Center in Irvine, CA, on September 27-29. The committee completed its final report draft and plans to send it to review in January 2007. The report should be released by spring 2007.
- The **ad hoc Committee on NASA Astrophysics Performance Assessment** met at the National Academies' Keck Center in Washington, DC, on October 20-22. The meeting was devoted to writing the draft of the committee's final report. The committee made substantial progress and sent the report to external review at the end of the calendar year.
- The **Task Group on Organic Environments in the Solar System** did not meet during this quarter. The task group's principal activities during this period concerned the revision of the report in response to additional comments by the Review Coordinator. Following the completion of a second set of responses on November 21, the Review Coordinator approved the revised text for release. The report is currently being prepared for publication by The National Academies Press and is scheduled for public release in late January 2007.
- The **ad hoc Committee on the Scientific Context for the Exploration of the Moon** held its third meeting on October 25-27, in Santa Fe, NM, to assess the response of the lunar science community and NASA to the interim report and to continue work on the final report. The committee heard presentations from NASA staff, other experts, and members of the committee. The committee held telecons on December 7, 13, and 19, to discuss progress on the final report; and during the December 13 session, to hear details on NASA's lunar architecture from NASA staff. The committee also proposed outreach activities to engage the lunar science community during the American Astronomical Society Division for Planetary Sciences meeting in Pasadena, CA, October 2006 and the American Geophysical Union meeting in San Francisco, CA, December 2006. Additional telecons are scheduled for January 2007, and the final meeting is set for February 13-15, 2007, in Boulder, CO. The final report is scheduled for release in the second quarter of 2007.
- The **ad hoc Committee on the Solar System Radiation Environment and NASA's Vision for Space Exploration: A Workshop** released its report October 23. The Executive Summary of the report appears in the *New Releases* section of this newsletter.
- An **ad hoc Committee on Research Enabled by the Lunar Environment,** consisting of five to six members, will organize a workshop to gather community input on the key scientific and technological questions that can be addressed on or from the Moon. The study will focus on science related to exploration systems and technologies as opposed to planetary science, which is the topic of another study that is currently underway. The ad hoc committee will review input from the workshop, past reports, and relevant NASA workshops, including a NASA Advisory Council workshop on lunar science scheduled for Feb. 27-Mar. 1, 2007. This activity is intended to be a precursor to further studies to assess the key issues identified. Membership selection and resource collection for this activity is underway.
- A public **Workshop on Decadal Science Strategy Surveys** was held on November 14-16, 2006, at the National Academies' Beckman Center in Irvine, CA. The purpose of the workshop was to promote discussions of the use of NRC decadal surveys for developing and implementing scientific priorities, to review lessons learned from the most recent surveys, and to seek to identify potential approaches for future surveys that can enhance their realism, utility, and endurance. The workshop, which was organized by a planning group drawn from the membership of the Space Studies Board, involved approximately 60 participants from academia, industry, government, and the NRC. A summary report of the workshop presentations, panel discussions, and general discussions on the use of NRC decadal surveys for developing and implementing scientific priorities in astronomy and astrophysics, planetary science, solar and space physics, and Earth science is being prepared for release in spring 2007.
- The **Committee on Space Research (COSPAR)** did not meet during the last quarter of 2006. The next meetings of the COSPAR Program Committee, the Publications Committee, Bureau and Science Advisory Committee will be held the week of March 19, 2007, at COSPAR Headquarters in Paris, France. The Spring meetings will focus on planning for COSPAR's 37th Scientific Assembly to be held in Montreal, Canada in 2008. More information on the 2008 Assembly is available at http://www.cosparhq.org/Meetings/Scientific_Assembly_Overview_2008.htm. COSPAR is also planning a 50th anniversary celebration, which will be held on July 14 during the 2008 Scientific Assembly (see http://www.cospar2008.org/anniversary_e.shtml). In addition, COSPAR will participate in a commemoration of 50 years of the space age (starting with the launch of Sputnik in October 1957) on March 21, 2007, which is being hosted by the United Nations Office for Outer Space Affairs, in cooperation with COSPAR, the International Astronautical Federation, and the United Nations Educational, Scientific and Cultural Organization (UNESCO). In other news, COSPAR Headquarters has relocated to the French space agency, CNES (Centre National d'Études Spatiales), following the French government's decision to sell the International Council for Science building where COSPAR was previously located.

NEW RELEASES FROM THE SSB

Summaries are reproduced without references, notes or attachments. Copies of reports are available from the SSB office at 202-334-3477 or online at http://www.nap.edu/.

Space Radiation Hazards and the Vision for Space Exploration: Report of a Workshop

This report by the ad hoc Committee on the Solar System Radiation Environment and NASA's Vision for Space Exploration: A Workshop is available online at http://books.nap.edu/catalog/11760.html. The study was staffed by Dwayne A. Day, study director, Arthur Charo, senior program officer, Catherine A. Gruber, assistant editor, and Celeste Naylor, senior program assistant. The following is the Executive Summary of the report.

Executive Summary

The President's Vision for Space Exploration (VSE) specifies that the United States should carry out a human lunar mission no later than 2020 and eventually conduct human expeditions to Mars. NASA has already been restructured to achieve these ambitious goals. This new policy creates many challenges, but not all of them are immediately obvious. Among these, the hazards of space radiation to crews traveling to the Moon and Mars will pose unique questions and challenges, not only to the spacecraft engineering community but to the space science community as well. Between the Apollo 16 and 17 missions in August 1972, for example, a powerful solar event occurred that would have seriously endangered astronauts on the lunar surface. Now that the United States has adopted a civilian space policy that refocuses many NASA research and engineering missions toward the human and robotic exploration of the Moon, Mars, and eventually other solar system bodies, events such as the powerful solar storms between Apollo missions over three decades ago must be interpreted in a new context.

Astronauts and spacecraft participating in the VSE will be exposed to a hazardous radiation environment, made up of galactic cosmic radiation and driven by solar energetic particle events and "space weather" changes. Accurate and timely information about this environment is required in order to plan, design, and execute human exploration missions. The information required consists of estimates or measurements of the time of occurrence, duration, and spatial distribution of the radiation, as well as the type, maximum intensity, and maximum energy of the constituent particles. Unfortunately, the prediction and forecasting of solar activity and space weather are severely hampered by a lack of understanding of how the Sun affects the heliosphere and planetary environments of Earth, the Moon, and Mars. Scientific progress in this field, leading to accurate long-term and short-term predictions of the space radiation environment, is required if solar and space physics scientists are to make the significant contribution required of them by human exploration missions.

A workshop held on October 16-20, 2005, in Wintergreen, Virginia, and cosponsored by NASA, the National Science Foundation, and the National Research Council brought together members of the space science, planetary science, radiation physics, operations, and exploration engineering communities. (The list of workshop participants and the agenda are presented in Appendix C.) The objectives of the workshop were to increase awareness and understanding of the complex array of solar and space physics issues pertinent to the environments of Earth, the Moon, and Mars; to identify compelling research goals necessary to ensure the success of the Vision for Space Exploration in these environments; and to discuss the directions that research in these fields should take over the coming decades in order to achieve these goals. The workshop effectively recognized that a multidisciplinary approach to defining the challenges of human exploration is required because no single National Academy of Sciences decadal survey or combination of surveys provides the type of advice needed for the new programs that are anticipated under the Vision for Space Exploration. Also, no single scientific or engineering discipline can provide the expertise and knowledge necessary to solve these problems optimally.

The workshop placed particular emphasis on the following topics:

- The heliospheric radiation environment as understood to date, including required data sources and possible new measurements;
- Physical mechanisms of energetic particle acceleration and transport in the heliosphere as understood to date;
- Radiation health hazards to astronauts;
- Radiation effects on materials and spacecraft systems; and
- Mitigation techniques and strategies, including forecasting and operational schemes.

A central theme that emerged during the workshop, both in the formal presentations in the plenary sessions and in focused discussions in thematically organized working groups, is the importance of the timely prediction of the radiation environment for mission design and mission operations. **There was general agreement among the participants that it is in this area that the solar and space physics community can, through improved characterization and understanding of the sources of space radiation, contribute substantively to NASA's radiation management effort and to the Vision for Space Exploration.** This statement may seem self-evident, but many workshop participants noted that it represented a change in attitude from previous community meetings. During the workshop, many of the participants focused for the first time in decades on ways that their research corresponds with NASA's needs to support humans traveling beyond low Earth orbit. Among the points that the workshop participants agreed on were the following:

- Developing timely predictions of the radiation environment is a complex task whose components vary depending on the timescale considered and on the mission characteristics;
- Delivering timely predictions requires advances in basic space and solar physics, development of observational assets, improved modeling capabilities, and careful design of communications;
- The space operations community—that is, those who plan and manage human spaceflight missions—must be informed about these advances in understanding and expanding capabilities so that operators can take advantage of advances; and

- In some cases operational tools (i.e., tools for space operations) must be developed or adapted from scientific analytical tools and converted to real-time reporting tools; the transition from research to operations is a very challenging task.

The workshop effectively assessed the following topics: the current level of understanding of solar and space physics; the issues faced by the NASA space radiation program as it deals with radiation effects on humans; the challenges of ensuring the reliable functioning of instruments and machines in space; and how progress can be made in understanding, defining, and, ultimately, making timely predictions of the space radiation environment.

Workshop participants made clear that current or planned research tools could be adapted to support the implementation of the Vision for Space Exploration. There was great enthusiasm about the ability to contribute to this endeavor. Rather than developing entirely new hardware or products, the space operations community can exploit many existing assets. However, many of the workshop participants also expressed the concern that a primary challenge will be knowledge transfer—that is, arranging existing data sets, models, research tools, and other assets in ways that make them useful to the space operations community. The solar and space physics community and the human spaceflight operations community do not have extensive existing ties, and this lack presents a barrier to effective collaboration. Better communication between these communities must be established; it will provide substantial benefits. Many workshop participants stated that NASA should conduct future interdisciplinary meetings similar to the Wintergreen Workshop to help coordinate the work of scientists and operators.

The nature of the workshop as an interdisciplinary forum demonstrated how it was possible that the space operations community might benefit from completely unexpected sources of data that it might never have realized existed except for such a collaboration. For example, recent studies of historical data from polar ice core samples suggest that solar events much larger than the August 1972 event have occurred during the past several hundred years. The largest of these events appears to have been the Carrington event of 1859. Estimates of possible organ doses from an event of this magnitude (~4 times larger than occurred in August 1972) indicate that substantial shielding would be needed to protect human crews in space. Astronauts performing extravehicular activities in space or surface exploration activities on the Moon during an event of this magnitude could receive potentially lethal exposures. Because NASA is contemplating stays on the lunar surface that may eventually last up to 6 months, there is a much higher probability of crews being exposed to a significant solar event than during the much shorter Apollo missions (which lasted no longer than 2 weeks from launch to landing).

Knowledge of the space radiation environment of the past provides the historical context for understanding the space radiation environment of the present. However, it also requires caution in extrapolating from present conditions to those that might exist in the future. With respect both to galactic cosmic radiation (GCR) intensity and to the frequency with which large solar energetic particle (SEP) events occur, the radiation environment at 1 AU appears at present to be relatively "mild." The historical record suggests that this is unusual and that if this mild interregnum ends, there might be significant consequences for human exploration.

Given the significant contribution of GCR to total radiation exposure of astronauts, it is important to understand long-timescale (decades or more) variations in the GCR. It is well established that at short timescales (months to years) the GCR flux varies with solar activity, peaking at solar minimum. But over longer timescales, the solar cycle amplitudes also vary. Some solar maxima are more intense than others. During a period known as the Maunder minimum, the number of sunspots, a measure of solar activity, essentially dropped to zero; hence the GCR flux would have been greater. What happens to the GCR intensity at such times? Recent solar cycles have had relatively large amplitudes, suggesting that the present may be a period of relatively low peak GCR intensities.

The workshop showed that a multidisciplinary approach could potentially reduce the costs of separate research efforts through the sharing of information. The information needed to meet solar and space physics objectives and to meet the requirements of the radiological health program often overlap. However, the priorities of the two areas generally differ. For example, a solar and space physics objective may require detailed particle energy resolution over a limited range of particle energies, while radiological health measurements require data for a broader range of energies but do not require the high resolution. Consequently, the data analysis phase of many solar and space physics experiments, constrained by budget limitations, did not recover all of the available information relevant to radiation protection. As a result, significant information relevant to radiological health may be available for a modest investment in the further analysis of existing data sets. Similarly, minor modifications to proposed solar and space physics instruments may result in data that will meet radiological health protection requirements, thereby eliminating the need for additional instruments intended solely for health protection measurements.

The Vision for Space Exploration raises important questions about how to determine that the knowledge base and predictive capabilities are adequate to commit crews to even longer missions to Mars. Currently, NASA's regulations governing acceptable radiation doses for human crews in low Earth orbit are for intervals significantly less than the 1,000 days it would take to send a crew to Mars. This limit is established by taking into account many poorly understood biological factors, and NASA is making progress toward reducing the size of the uncertainties. As several workshop participants noted, merely reducing the amount of uncertainty in the understanding of radiation health effects can significantly increase the number of days allowable for human crews to spend in space. But NASA will have to make a concerted research effort to reduce that uncertainty; it will not happen without planning.

Space radiation not only affects humans but can affect spacecraft, instruments, and communications as well. Some of these effects are well known, such as electrostatic charging and degradation of solar cells. Solar particles, cosmic rays, and trapped particle radiation are all of concern in this regard. Certainly a reduction in uncertainty about such radiation will improve spacecraft design and operations.

Global radiation models are beginning to become available, but they are difficult to tailor to specific events. One clear statement from the workshop is that there is a need for a better understanding of how to relate solar and space physics observations to the models.

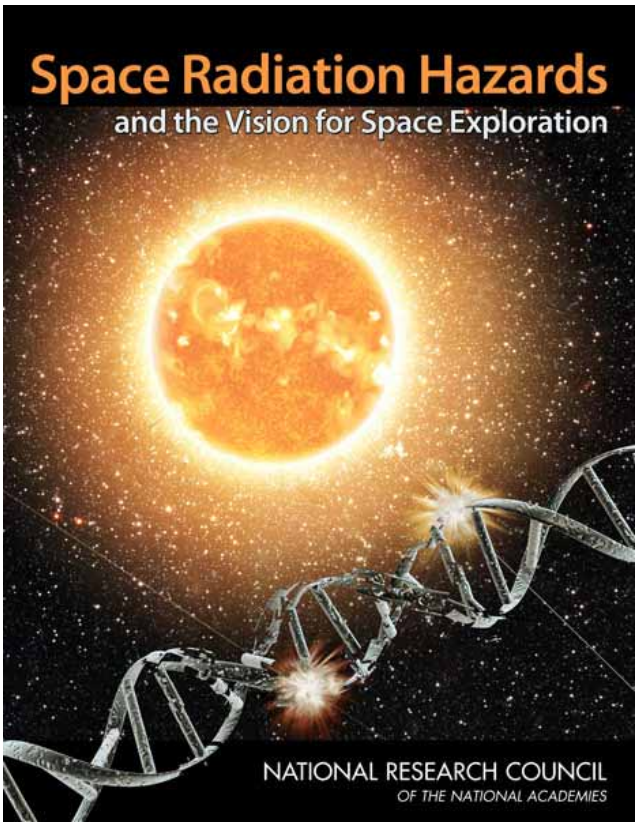
The observations have a dual role: (1) they provide the inputs to drive models, and (2) they are required to validate the models (post facto). For the near-term need, it should be possible to improve predictions of "all clear" periods when there is a very low probability that an SEP event will occur. This is possible with a better understanding of the signatures indicating that a flare or coronal mass ejection is about to erupt. New observations of solar magnetic structures with Solar-B, the Solar Dynamics Observatory, and the ground-based Advanced Technology Solar Telescope and the Frequency Agile Solar Radio Telescope will help in this regard.

Farther in the future, it is desirable to make predictions of solar events days to weeks before they occur. Initially, this will be possible only with models that use a statistical approach along with a suitable set of in situ and remote sensing measurements from multiple vantage points in the heliosphere. It will be most useful for the Vision for Space Exploration if models can predict the following: (1) the onset time for an SEP event, (2) its time-intensity profile, (3) the "spectral indices" of the energy spectrum, (4) the shock arrival time, and (5) the anisotropy in the particle velocity distribution (a lower priority). An effective warning system for SEP events will require an operational distributed network of observations from the Sun throughout the heliosphere (similar to the distributed network of weather stations on Earth). Near-Sun missions such as Inner Heliosphere Sentinels, Solar Orbiter, and Solar Probe will provide unique measurements to test more sophisticated models. Recent physics-based (dynamo) models of the Sun give hope of making accurate predictions of the size of solar activity cycles years or decades in advance.

Because of the threat posed by SEP events, taking radiation safety into account will be critical in order to ensure adequate shielding or timely access to a safe haven. Fortunately, awareness of the risk of radiation exposure is widespread, and it is hoped that systems will be designed to manage radiation risk. It is critical to decide at the outset what the radiation risk mitigation strategy will be and then to integrate this strategy into the mission concept early in the design phase. The generic elements of a radiation risk mitigation strategy include space environment situational awareness, radiation exposure forecasting, and exposure impact and risk analysis. These elements combine to generate recommendations to the mission commander, who has the responsibility for keeping the radiation exposure as low as reasonably achievable.

The large uncertainties in space radiation and biological effects that exist at present increase the cost of missions owing to the large safety margins required as a consequence. These uncertainties also limit the ability to judge the effectiveness of risk mitigation methods, such as improvements in shielding or biological countermeasures. Operational measures and radiation shielding are currently the main means of reducing radiation risk; improved biological markers have the potential to enable improved early diagnostics; discovery of means of biological prevention and intervention may lead to significantly more powerful methods, including better radioprotectants, to overcome the biological consequences of exposure to radiation. Continued basic research has the potential to address all of these key issues effectively.

The challenges described here can be overcome, and NASA is making progress on many of them. But the hazards of space radiation to future space explorers can only be reduced with the assistance of the solar and space physics science community and effective collaboration between the scientists and the space operations community.



SPACE STUDIES BOARD STAFF NEWS

New SSB Research Associate

Victoria Swisher joined the SSB in December as a Research Associate. She recently graduated from Swarthmore College with a major in astronomy and a minor in english. She previously studied the X-rays from DoAr 21, a young star, the results of which she presented at the 2005 American Astronomical Society (AAS) meeting, as co-author of a talk at the 2006 AAS meeting and at various Keck Northeast Astronomy Consortium (KNAC) undergraduate research conferences. Her most recent research focused on laboratory astrophysics, studying the X-rays of plasma, culminating in a senior thesis titled "Modeling UV and X-ray Spectra from the Swarthmore Spheromak Experiment." Victoria is already enjoying the opportunity the SSB is giving her to learn more about space and science policy.

SSB Winter Space Policy Intern

Emily McNeil joined the SSB at the end of November and will be working with us until February 2. She graduated from Middlebury College in May 2006 with a BA in physics. Her undergraduate research in observational astronomy concluded with the presentation of an American Astronomical Society (AAS) abstract on optical supernova remnants in M33 at the June 2006 meeting. Emily's interest in space science policy developed when she presented her work on Capitol Hill at the Posters on the Hills session to lobby for undergraduate research funding agencies. At SSB, Emily has had the opportunity to work with several study directors on projects ranging from Mars Astrobiology to Earth Science and Applications from Space. Emily will start her doctoral work in astrophysics this February at Australian National University in Canberra, and hopes to return to Washington, DC for a career in science policy.

Professional Society Meetings

Barbara Akinwole, SSB Information Management Associate, attended the American Geophysical Union (AGU) Meeting, December 11-15, 2006.

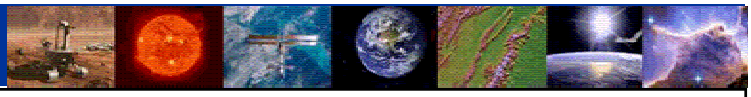
The Space Studies Board (SSB) has been an exhibitor at the American Geophysical Union (AGU) fall meeting since 2000. Over the course of six years, Board staff members have distributed thousands of complimentary copies of study reports to AGU attendees. These reports cover a wide range of discipline areas, including Earth science, solar and space physics, astronomy and astrophysics, planetary sciences and exploration, and life sciences.

The AGU provides a forum for exchange of ideas within the science community and it also offers the general public access to technical information and materials that have been popularized for a general audience.

The 2006 AGU fall meeting, which posted a record registration of 13,800 plus, proved to be especially rewarding for the SSB. While our reports are always well received, this meeting provided us with several anecdotes to support this claim. The most memorable of which is the attendee who approached the SSB booth with a glint in his eyes and proceeded to pick up first, the *Space Radiation Hazards and the Vision for Space Exploration*: *Report of a Workshop*, as he exclaimed, "this is just why I came here, they are just what I need, these are the reports;" and with a broad grin, he continued in his happy pursuit as he picked up copies of *Distributed Arrays of Small Instruments for Solar-Terrestrial Research*: *Report of a Workshop*; *Exploration of the Outer Heliosphere and the Local Interstellar Medium: A Workshop Report*; *Solar and Space Physics and Its Role in Space Exploration*; and *Plasma Physics of the Local Cosmos*. He thanked us profusely and left with a bag full of reports.

In addition to the above mentioned reports being, "just what the AGU attendees needed," our popularized versions of the solar and space physics decadal survey (*Understanding the Sun and Solar System Plasmas: Future Directions in Solar and Space Physics*) and the solar system exploration decadal survey (*New Frontiers in Solar System Exploration*) were in high demand.

Copies of SSB reports are available free of charge while supplies last. Visit our website at http://www7.nationalacademies.org/ssb/ to see a list of all reports the most recent reports.



SELECTED REPORTS AVAILABLE FROM THE SPACE STUDIES BOARD

All reports are available free of charge while supplies last.

Print this form and enter the number of reports you wish to receive in the space to the left of each report.

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___ Space Radiation Hazards and the Vision for Space Exploration: Report of a Workshop **(CD only)**

___ A Review of NASA's 2006 Draft Science Plan: Letter Report

___ The Scientific Context for Exploration of the Moon: Interim Report

___ Space Studies Board Annual Report 2005

___ Assessment of NASA's Mars Architecture 2007-2016

___ An Assessment of Balance in NASA's Science Programs

___ Issues Affecting the Future of the U.S. Space Science and Engineering Workforce: Interim Report

___ Assessment of Planetary Protection Requirements for Venus Mission: Letter Report

___ Review of NASA Plans for the International Space Station

___ Extending the Effective Lifetimes of Earth Observing Research Mission **(Limited Quantity)**

___ Priorities in Space Science Enabled by Nuclear Power and Propulsion **(CD Only)**

___ Review of Goals and Plans for NASA's Space and Earth Sciences

___ Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation

___ Assessment of Options for Extending the Life of the Hubble Space Telescope: **(CD only)**

___ Utilization of Operational Environmental Satellite Data

___ Understanding the Sun and Solar System Plasmas—a 40-page full color booklet based on the report The Sun to Earth—and Beyond: A Decadal Research Strategy in Solar and Space Physics

___ Issues and Opportunities Regarding the U.S. Space Program: A Summary Report of a Workshop on National Space Policy

1998-2003

___ New Frontiers in Solar System Exploration – a 32-page full color booklet based on the SSB report New Frontiers in the Solar System: An Integrated Exploration Strategy. **(Limited Quantity)**

___ The Sun to the Earth—and Beyond: Panel Reports

___ Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations

___ Using Remote Sensing in State and Local Government: Information for Management and Decision Making

___ Assessment of Directions in Microgravity and Physical Sciences Research at NASA

___ Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research

___ New Frontiers in the Solar System: An Integrated Exploration Strategy

___ The Sun to Earth—and Beyond: A Decadal Research Strategy in Solar and Space Physics

___ The Quarantine and Certification of Martian Samples

___ Issues in the Integration of Research and Operational Satellites for Climate Research: I. Science and Design

___ Issues in the Integration of Research and Operational Satellite Systems for Climate Research II. Implementation

___ Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies

___ Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making **(Limited Quantity)**