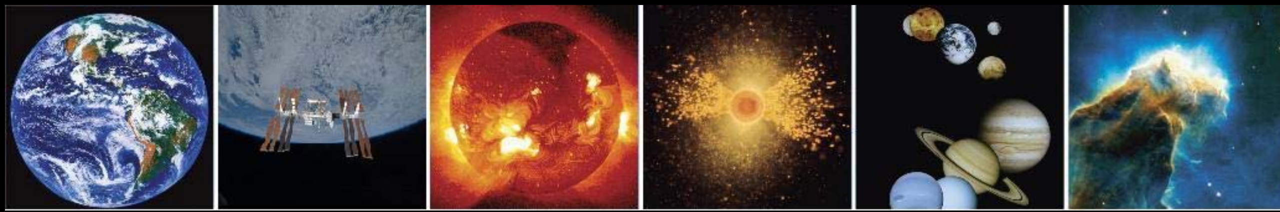
SPACE STUDIES BOARD NEWS



OCTOBER—DECEMBER 2009

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—Charles F. Kennel, Chair, SSB

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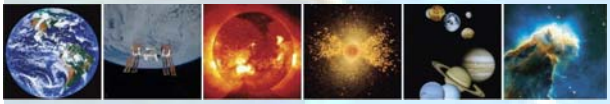


FROM THE CHAIR

The recent report of the Augustine Commission has focused attention on the decisions about human space flight that NASA must make in the coming year. This is understandable, given the importance of human spaceflight to NASA as an institution. It is also timely, because the imminent retirement of the space shuttle requires a major change in how human exploration of space will proceed in the next generation.

Yet, as I write this, COP-15, the Copenhagen conference on climate change, has just concluded. I find myself asking whether the most *far-reaching* decisions NASA makes next year could actually be about Earth science. And I am beginning to wonder whether our Decadal Survey for Earth science has been overtaken by events.

The scientific vision embodied in the Decadal Survey is spot on. A comprehensive observational strategy is needed to address the fundamental questions of Earth system science, and Earth system science so far provides the only scientific framework that can adapt to the evolving needs for knowledge about the changing climate and its impact. The Decadal Survey is widely regarded as the best available roadmap to the future of the U.S. space component of Earth system science.

So the problem is not the Decadal Survey's scientific vision or its credibility. Part of the problem has certainly been its delayed and incomplete implementation. Not only was Earth science funding allowed to decline in the past decade, but the NPOESS disaster pushed back the time when many important climate observations will become regularly available. The missions recommended in the Decadal Survey will also arrive later than envisioned, and some may not arrive at all. I fear some synergies needed to support the system approach to observations may be compromised.

My experience with the Earth Observing System, whose replacement the Decadal Survey designed, taught me two basic lessons. First, a mission designed for one purpose often proves much more flexible after flight experience has been gained and the data analysts get moving. Second, and here is my main point, missions conceived and designed for pure science often end up performing crucial policy functions.

"...the most *far-reaching* decisions NASA makes next year could actually be about Earth science."

Policy makers are not waiting for the research to operations transition, itself a subtle sign of how quickly climate issues are evolving. Given this, it is unwise to design an observational strategy for Earth system science without anticipating the policy demands that will be placed upon it. Those demands are bound to change in the aftermath of COP-15. So let us speculate on how they may change, since soon the White House and Congress may place new demands on NASA and NOAA.

It was always going to be difficult to reach a binding agreement to limit greenhouse gas emissions. Negotiations among 193 sovereign countries are bound to be exceptionally complex. They are made more difficult when not all parties are enthusiastic. Verification is a sticking point, there are few credible sanctions for enforcement anyhow, and, inevitably, money is involved. These factors are inherent to the negotiation process and have little to do with technical substance. So we probably can expect a continuation of the present series of laborious climate negotiations for the foreseeable future. This means that political progress at the global level will be incremental and slow.

Even had COP-15 achieved a global agreement on carbon emissions, it would have taken decades to implement it at a global scale. While technological breakthroughs are on the horizon, the global deployment of new energy technologies will take a long time. As if these facts were not enough, the climate appears to be changing faster than was thought only a few years ago. Greenhouse gas emissions and sea level rise are running ahead of the forecasts of the 2007 IPCC assessment. Thus, scientific, technological, and political considerations all point to the conclusion that there will be significant, unavoidable climate change.

Our strategy henceforth will have to be, in the words of NAS President Ralph Cicerone, "avoid the unmanageable, and manage the unavoidable," referring to the 2007 report of the Scientific Expert Group on Climate Change.

Adaptation and mitigation have equal political weight for the first time. Space observations become even more important as a result, because they are more pertinent to adaptation than they are to mitigation. But there will be different customers for the observations. Global climate assessments were largely designed to reach a relatively small number of central decision makers concerned with mitigation, whereas adaptation will call for decisions from millions of decision makers in hundreds of localities and for hundreds of specific issues.

Regional climate assessments speak directly to the specific things local people care about, and the regional assessments carried out to date have proven to be effective at connecting to local decision-making. This emerging regional emphasis calls for reshaping the tools of science and policy thus far deployed for mitigation to also serve adaptation and local, rather than global, decision making. Supporting local decision making also demands linkage with the broader sustainability agenda, because at the local-level adaptation to climate change is intertwined with regionally and culturally specific economic and social concerns.

Because of the slow progress at the global level, we can anticipate a political realignment around regional foci. Subsidiary alignments amongst countries and regions with common interests are already emerging. Mayors are networking. California's governor, Arnold Schwarzenegger, is calling for regional approaches to climate change and a network of cooperating regions. The subsidiary political structures that are forming before our very eyes will call for a highly differentiated approach to observations and information management.

Not only are smaller political units stepping up to the challenge of climate change, so also are private companies. This is not entirely for altruistic reasons. In our area, aerospace companies, having achieved the fusion of platform, sensors, communications, and information management required for situational awareness on the battlefield, are asking whether their experience can be applied to environmental management. Information technology companies are wondering whether there is a large future business in providing environmental information to decision makers around the world. And there are some companies preparing to invest their own funds to find out. By participating in research and pilot projects, they hope to understand their potential customers better.

NASA can help with this. Therein lies a significant opportunity. NASA could anchor a network of public-private partnerships that aggregate private resources into efforts that can work at scale. In fact, NASA has already begun. At COP-15, NASA and Cisco Systems announced the formation of the "Planetary Skin Institute" as a non-profit 501c(3). Funded by a consortium of private companies, the Institute aims to be a virtual research network advancing the use of observations, analysis, and modeling in decision support. It will have hubs in India, China, Japan, Europe, Brazil, Africa, and the United States.

Does the Planetary Skin Institute presage a new way to realize the goals of the Decadal Survey while addressing the new emphases emerging from climate negotiations? This would be a new way of doing business, akin to the Augustine Commission's recommendations that private entrepreneurial companies be put in the critical path of space station re-supply. Both ideas seem worth considering.

It is tempting to ask whether we would have designed or implemented the Decadal Survey the same way had we known 5 years ago what we know now. But that would not be productive. The better question is, knowing what we know now, what do we do now?

—Charles F. Kennel, Chair, Space Studies Board

DIRECTOR'S CORNER

This will be my last report as acting director of the SSB. Michael Moloney will be taking over most of the responsibilities on April 1 and assume the job completely sometime in the late summer, as he completes the Astro2010 study. Michael has been sitting in on various staff meetings so far, and we are consulting with him on those decisions that are likely to affect his tenure. This transition is going smoothly and should make for a nearly seamless transfer of management.

Michael has a great deal of experience at the NRC on a wide variety of projects. While most of the time has been spent with the Board on Physics and Astronomy (BPA), he directed several projects for our National Materials Advisory Board, including one for the Treasury Department on technologies for combating evolving counterfeiting threats. He also worked on a joint project with the Division of Behavioral and Social Sciences and Education on national content of imports and exports. In addition to his project experience with BPA, he served as deputy director for the past two years.

Michael's current project, the Astro2010 decadal survey, is one of the largest projects ever carried out at the NRC. It involves more than 100 volunteers on the various science and priority panels and on overarching survey committee. Management of this enterprise is a substantial undertaking and the experience will serve him well as he assumes directorship of the SSB with its numerous ongoing studies. I am confident that Michael will be able to carry on in the tradition of Marc Allen, Joe Alexander, and Marcia Smith and build on their accomplishments to continue the outstanding record of the Board.

I will be returning to my job as DEPS deputy executive director gradually over the next several months. Part of that assignment will involve working on a couple of projects outside the space and aeronautics area. In addition, I will be continuing to work with some of the SSB activities, including the Board's November workshop.

This past year has been most interesting and very full, as we launched a large number of projects. Many of those are near completion, and we are in the process of starting a number of new projects. Interest in U.S. civilian space policy has intensified the past several months, driven by the Augustine Commission report, the increased attention on climate change, and growing pressure on the federal budget. Our report, *America's Future in Space*, is playing an important role in helping the administration and Congress come to grips with what this policy should be. I expect the Board will be quite busy for the next several months, as it is called on to assist in implementation of the new policy.

I have enjoyed very much working with the SSB staff and the members of the Board this past year. I will be leaving with mixed feelings—relieved from the management pressures but missing them at the same time. I know that my e-mail traffic will drop substantially and maybe I can finally clear up the large back log. Finally, I offer my sincere thanks to the staff, the Board, the standing committees, NASA, the volunteers, and everyone else who has helped me with this assignment.

—Richard Rowberg, Acting Director, SSB and ASEB

SSB ACTIVITIES

THE BOARD AND ITS STANDING COMMITTEES

The **Space Studies Board (SSB)** met at the National Academies' Arnold and Mabel Beckman Center in Irvine, CA, November 3-4, 2009. The major focus of the meeting was the Augustine Commission Report with briefings from Commission members Ed Crawley (MIT) and Jeff Greason (XCOR Aerospace). In addition, David Bearden (Aerospace Corporation) reviewed the cost estimate methodology used by the Commission. The Board also heard congressional views of the Commission's report from Chan Lieu and Jeff Bingham of the Senate Commerce Committee and Dick Obermann of the House Science Committee. The Board was also briefed by Mark Uhran (NASA) on the enhanced utilization plan for the International Space Station.

The workshop originally planned for this meeting was rescheduled for November 2010.

The **Committee on Astronomy and Astrophysics (CAA)** is on hiatus until the completion of the astronomy and astrophysics decadal survey.

The **Committee on Earth Studies (CES)** met on October 19-20 in Washington, DC, and received briefings from Mary Kicza, NOAA assistant administrator for satellite and information services, and from Michael Freilich, director of NASA's Earth Science Division. Committee discussions focused on issues related to the implementation of the decadal survey, *Earth Science and Applications from Space*, the status of NPOESS, and potential workshops or studies of interest to agency sponsors. The committee also received updates on several prospective and ongoing NRC studies.

The **Committee on the Origins and Evolution of Life (COEL)** did not meet during this quarter. Their scheduled December meeting was cancelled and replaced by a conference call held on December 3. In support of a potential future study project, a subset of committee members, including co-chair Robert Pappalardo, and committee staff participated in COSPAR's Icy Satellites Planetary Protection Workshop, held at the California Institute of Technology on December 9-10. The committee's next meeting will be held at the University of Southern California on February 17-19, 2010. The dates of future meetings will be set in the near future.

The **Committee on Planetary and Lunar Exploration (COMPLEX)** is on hiatus until the completion of the Planetary Science Decadal Survey.

The **Committee on Solar and Space Physics (CSSP)** met December 3-4, 2009, in Washington, DC. The meeting focused on planning for the upcoming heliophysics decadal survey, which will get underway in spring 2010. To that end, the committee received briefings from Richard Behnke (NSF), Tom Bogdan (NOAA), Dick Fisher (NASA), and Marc Allen (NASA). NASA, NSF, NOAA, and the DOD (Air Force and Navy) were sponsors of the previous decadal survey in solar and space physics, *The Sun to the Earth—and Beyond* (http://www.nap.edu/catalog.php?record_id=10477), which was completed in 2003. The committee was also briefed by Space Studies Board member Andy Christensen, who chaired the recently completed heliophysics roadmap for NASA. Dick Fisher presented the committee with an update on activities within NASA's Heliophysics Division. Lessons learned from previous and ongoing NRC decadal surveys were discussed during briefings by several staff members of the Space Studies Board.

The committee plans to meet early in 2010 to finalize plans for initiation of the survey; after this meeting, the committee will stand-down until completion of the survey, which is anticipated in early 2012.

STUDY COMMITTEES

The ad hoc **Committee on the Assessment of Impediments to Interagency Cooperation on Space and Earth Science Missions** did not meet this quarter; however, the committee held bi-weekly teleconferences and several members participated in a November 2 meeting that was held in conjunction with the November 3-4 meeting of the Space Studies Board in Irvine, CA. The committee continued work on its draft report with the expectation that an NRC-approved prepublication will be available by March 31, 2010.

Congress directed NASA to arrange for an independent **Assessment of NASA Laboratory Capabilities**; as a result, the NRC's Laboratory Assessments Board, in collaboration with the SSB, formed an ad hoc committee of 20 members to carry out a review of NASA's laboratories to determine whether they are equipped and maintained at a level adequate to support NASA's fundamental science and engineering research activities. Following an initial data-gathering meeting and a site visit to Goddard Space Flight Center in the 3rd quarter, additional site visits were organized to Glenn Research Center on October 15-16, Langley Research Center on October 21-22, and Ames Research Center (aeronautics activities only), and the Jet Propulsion Laboratory on November 9-10. The second full committee meeting was held at the Beckman Center on November 11-12; agreement was reached on the overall report philosophy and format and writing assignments were made. The committee decided to go ahead with two additional site visits—a subgroup visited Ames Research Center's space activities on December 2-3 and another subgroup visited the Marshall Space Flight Center on December 10. The third and final committee meeting will be held on January 19-20, 2010, at the Keck Center in Washington, DC.

The **Astronomy and Astrophysics Decadal Survey Committee (Astro2010)** continues to move forward. The nine panel reports recently entered the NRC's peer-review process and the survey committee will hold their last two (closed) meetings at the end of January and February. The survey committee's report is scheduled to enter NRC review in the spring. The prepublication versions of the survey committee report and the panel reports are expected to be released later this summer. Check the survey's webpage at www.nationalacademies.org/astro2010 for further updates on the release of the reports.

The **Steering Committee for the Decadal Survey on Biological and Physical Sciences in Space** met on October 14-16, in Washington, DC to hear presentations on the European and Japanese microgravity programs, as well as presentations on research opportunities that could potentially become available on commercial spacecraft. The majority of the meeting was reserved for closed session discussions on the status of efforts to recruit community input, review of materials drafted by the panels, and report development and planning activities. A telecon was held with the seven panel chairs for this study during the meeting. Following the meeting, the steering committee continued to hold frequent joint telecons with individual panels in order to provide input and guidance.

After a broad canvassing of the relevant communities, the solicitation of white papers for this study was completed in mid-October, with the receipt of about 150 papers from the community (many with multiple authors) . The white papers covered a wide number of disciplines relevant to the study and were subsequently reviewed by each of the seven study panels and the steering committee. Three town halls were held in conjunction with scientific society or technical meetings during this period— meetings of the American Society for Gravitational and Space Biology, the Lunar Exploration Analysis Group, and the American Society of Mechanical Engineers. At each of these meetings, steering committee members presented information on the study and led discussions aimed at soliciting input on important research and programmatic issues.

Nine meetings of the various study panels were held in this period to gather and assess inputs from a wide range of sources, including invited presentations, and to continue development of chapters and recommendations for the report. In addition to regular meetings, the panels have continued to hold telecons throughout this period in order to address report development issues. Regular meetings of the panels will be completed by the end of January 2010.

Updates and detailed information on the study is provided on the public website at http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_050845. All of the submitted white papers can be viewed at this site as well.

The ad hoc **Committee on Cost Growth in NASA Earth and Space Science Missions** met for the third time in Washington, DC on December 3-4 where it focused on reviewing the report outline, developing consensus on findings and recommendations, and assigning draft sections of the report. Based on the progress at this meeting, the committee elected to schedule a fourth and final writing meeting for January 11-12, 2010, in Boulder, CO. The committee plans to have its draft report submitted for NRC review by late February 2010; the deadline for delivery to NASA of a prepublication version is May 1, 2010. The final printed report is expected to be completed and released in July 2010.

The ad hoc **Committee on NASA's Suborbital Research Capabilities** submitted its draft for NRC review in mid-October; the necessity for a lengthy, detailed response to the eleven reviewers pushed the sign-off for the report past its nominal deadline, and delivery to NASA of a prepublication version is expected in early 2010. The edited, final, printed report is expected to be released later in the first quarter of 2010.

The **Planetary Science Decadal Survey** continues its 2-year study to define a new science and mission strategy for solar system exploration activities at NASA and NSF. The survey's steering committee and four of its five supporting panels each held their second meeting during this quarter: steering committee, November 16-18 in Irvine, CA; Giant Planets Panel, October 26-28 in Irvine, CA; Inner Planets Panel, October 26-28 in Irvine, CA; Primitive Bodies Panel, October 28-30 in Irvine, CA; and Mars Panel, November 4-6 in Pasadena, CA. Presentations at these and other meetings, together with meeting summaries and archived webcasts, are available at the decadal survey's website: http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412. In addition, the decadal survey also held community-outreach events at meetings of the Division for Planetary Sciences of the American Astronomical Society (Fajardo, PR, October 4-9) and the American Geophysical Union (San Francisco, CA, December 14-18).

A major activity initiated during this quarter was the commissioning by the decadal survey of the first and second set of mission studies to be undertaken in support of the panels' prioritization activities. These studies are being undertaken at the Applied Physics Laboratory, Goddard Space Flight Center, and Jet Propulsion Laboratory. Additional studies will be initiated in early 2010. In a related activity, the decadal survey has engaged the services of the Aerospace Corporation to provide independent cost estimates for the highest-priority mission concepts resulting from these studies.

The steering committee lost the services of one of its members in November when Wesley T. Huntress, Jr., resigned to take up a new appointment on the NASA Advisory Council. George Paulikas has been appointed as his replacement.

Future meetings of the decadal survey's steering committee will take place on February 22-24, in Irvine, CA, and July 13-15, in Washington, DC. Note that the previously announced May 25-27 meeting had been cancelled. The panels will meet on the following dates: Satellites, April 12-14 in Boulder, CO; Mars, April 14-16 in Boulder, CO; Inner Planets Panel, April 21-23 in Boulder, CO; Primitive Bodies, April 26-28 in Knoxville, TN; and Giant Planets, May 5-7 in Boston, MA. Future outreach activities are planned for the Lunar and Planetary Sciences Conference (The Woodlands, TX, March 1-5), and the Astrobiology Science Conference (Houston, TX, April 26-28). The decadal survey is scheduled to be delivered to NASA and NSF by the end of March 2011.

The final report of the ad hoc **Committee for the Review of Near-Earth Object (NEO) Surveys and Hazard Mitigation Strategies** entered review in fall 2009. The committee and its panels undertook a two-phase study to provide recommendations addressing two major tasks: determining the best approach to completing the NEO census required by Congress to identify potentially hazardous NEO's larger than 140 meters in diameter by the year 2020 and determining the optimal approach to developing a deflection strategy and ensuring that it includes a significant international effort. Both tasks will include an assessment of the costs of various alternatives, using independent cost estimating. The committee's interim report was released in early August. The committee's final report will be released to the public on January 22.

The **Committee on the Role and Scope of Mission-Enabling Activities in NASA's Space and Earth Science Missions** completed external reviews of its draft report, *An Enabling Foundation for NASA's Earth and Space Science Missions*, in November. The pre-publication version of the report was delivered to NASA and congressional offices on November 30 and was released to the public on December 4. The National Academies Press is expected to have final printed editions of the report ready for distribution in February 2010.

SSB STANDING COMMITTEE CHAIRS

COMMITTEE ON ASTRONOMY AND ASTROPHYSICS (CAA)*

COMMITTEE ON EARTH STUDIES (CES)
Chair: Berrien Moore III
Vice Chair: Ruth S. DeFries

COMMITTEE ON THE ORIGINS AND EVOLUTION OF LIFE (COEL)**
Co-Chairs: Robert T. Pappalardo and J. Gregory Ferry

COMMITTEE ON PLANETARY AND LUNAR EXPLORATION (COMPLEX) ***

COMMITTEE ON SOLAR AND SPACE PHYSICS (CSSP)
Chair: Daniel N. Baker
Vice Chair: Thomas H. Zurbuchen

*Joint with the Board on Physics and Astronomy. CAA is on hiatus during the Astro2010 decadal survey.
**Joint with the Board on Life Sciences.
***COMPLEX is on hiatus during the planetary sciences decadal survey.

OTHER ACTIVITIES

The **Committee on Space Research (COSPAR)** will hold its next scientific assembly in Bremen, Germany, on July 18-25. Annual business meetings will be held at COSPAR's Paris headquarters on March 22-25. The membership term of Edward Stone, the current U.S. representative to COSPAR ends in 2010. The Space Studies Board, acting in its role as the U.S. National Committee for COSPAR, nominated Robert Lin of the University of California, Berkeley, as the new U.S. representative. The NRC's Executive Office ratified the nomination, and Dr. Lin will take over his new role on July 1.

OTHER NEWS

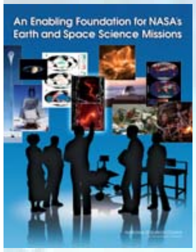
Daniel N. Baker, Space Studies Board member and chair of the Committee on Solar and Space Physics, was awarded the James A. Van Allen Space Environments Award for excellence and leadership in space research from the American Institute of Aeronautics and Astronautics (AIAA). Dr. Baker receives the award of excellence based on his work "in the study of the magnetosphere and its consequences for radiation effects on Earth-orbiting satellites."

Dr. Baker is a professor at the University of Colorado, Boulder, and director of its Laboratory for Atmospheric and Space Physics (LASP). He earned his doctorate at the University of Iowa working under James A. Van Allen.

NEW RELEASES FROM THE SSB

Copies of reports are available from the SSB office at 202-334-3477 or online at <www.nap.edu/>.

An Enabling Foundation for NASA's Earth and Space Missions



This report by the Committee on the Role and Scope of Mission-enabling Activities in NASA's Space and Earth Science Missions is available at http://www.nap.edu/catalog.php?record_id=12822. The study was led by Lennard A. Fisk (chair) and Bruce H. Margon (vice chair) and staffed by Joseph K. Alexander, Study Director, Carmela J. Chamberlain, Administrative Coordinator, Linda M. Walker, Senior Project Assistant, Victoria Swisher, Research Associate, and Catherine A. Gruber, Editor.

This report responds to direction from Congress in the Fiscal Year 2008 omnibus appropriations bill for an examination of NASA's research and analysis programs.

The study committee focused on the ensemble of programs that are not directly tied to specific spaceflight missions and that create the scientific and technological expertise and associated infrastructure necessary to define, execute, and benefit from scientific spaceflight missions. The committee consolidated these programs under the umbrella term "mission-enabling activities." The committee's report identifies the fundamental roles of mission-enabling activities in the context of the NASA Science Mission Directorate's (SMD's) strategic goals, defines principles and metrics for a robust and relevant portfolio of mission-enabling programs to fulfill these fundamental roles, and recommends best practices to maximize the effectiveness of mission-enabling programs.

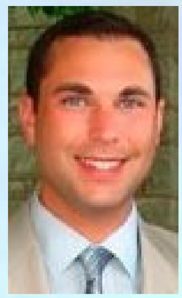
The mission-enabling activities in SMD—including support for scientific research and research infrastructure, advanced technology development, and scientific and technical workforce development—are fundamentally important to NASA and to the nation as well. The report recommends that SMD implement an active approach to managing its portfolio of mission-enabling activities that has the following key attributes:

- Explicit mission statements traceable to the overall strategic goals of NASA and SMD;
- Flexibility to accommodate differences in SMD's scientific divisions;
- Clear relationships to ongoing and future spaceflight missions,
- Clear metrics to relate mission-enabling activities to strategic goals and to facilitate program evaluation and decision making;
- Support for innovative high-risk/high-payoff research and technology, interdisciplinary research, and scientific and technical workforce development;
- Active involvement of the scientific community in the advisory committee process; and
- Transparent budgets that facilitate effective portfolio management and communications to parties outside NASA.

While the committee concluded that this approach can help maximize the value and impact of SMD's mission-enabling activities, the report also identifies one particularly serious obstacle. Specifically, the SMD headquarters staff is not adequately sized to manage mission-enabling activities effectively. Therefore, the report also recommends that NASA increase the number of scientifically and technically capable program officers so that they can devote an appropriate level of attention to the tasks of actively managing the portfolio of research and technology development that is the foundation of SMD's world-class space and Earth science program.

CONFERENCE SUMMARIES

Attended by Lewis Groswald, Research Associate



TEDxNASA: NASA Reaches Out to a Wider Audience

On November 18 NASA's Langley Research Center hosted a TED seminar at the Christopher Newport University (CNU) with the theme "Space to Create."

TED, which stands for technology, entertainment, and design, is a nonprofit dedicated to "Ideas Worth Spreading." Their mission is to put on events that bring together people with disparate but inspiring backgrounds and to share their stories with the audience, posting these videos online for the world to see. Talks range from a neuroscientist describing what it was like to have stroke, to heavyweights like Bill Gates and Al Gore talking about the work they do or causes they believe in. The "x" in TEDx means that this particular event was independently organized by the host (NASA Langley) but sponsored by TED.

The event was tied to NASA as a whole—not just the Langley Research Center. Surveying the speaker list and looking around the auditorium at the audience, it became clear that NASA was trying to reach out to the public in a new format and perhaps change public perception about the agency.

Naturally there was a large space contingent in the audience, even though the event rarely focused on space as readers of this newsletter might think of it. This was no doubt the point, as NASA seemed to want to capitalize on trends in the scientific, engineering, academic, and social justice communities that point to greater networking and communication between different groups, in turn benefiting them all. The TEDxNASA conference was based on increasing the interdisciplinary nature of research and promoting new ways of thinking for the attendees to solve problems, called "collective ingenuity."

The first speaker at the event was neuroscientist and professor Paul Aravich, who contends that the brain is the last frontier of science. He elaborated by saying that behavioral neuroscience is the last frontier of the last frontier of science, and that engineering is for wimps. Though not salacious, the comment was somewhat shocking, given that it was said at an event hosted by NASA. But this only underscores the overarching theme of the event, which was to challenge convention and perceptions.

Brenda Barrow, an award-winning math teacher from Texas, serenaded the audience with timeless numbers like "We love math, it's #1, we love math it's so much fun." Dennis Hong, research professor at Virginia Tech, talked about his work in robotics and touched upon parallels between his work and planetary exploration.

Space-related speakers included Joel Levine, a planetary and atmospheric scientist at NASA Langley and principal investigator of the proposed ARES Mars Airplane Mission, who is an advocate for the search for life on Mars. Anna McGowan, an aerospace engineer at NASA Langley, who spoke about her path from the dream of a 13-year old who wanted to become an engineer to working at NASA. Leland Melvin, astronaut on the STS-129 shuttle mission to the International Space Station, talked about his experiences as an astronaut and what it means to him as a human being and an American.

The effects on audience members and speakers alike is yet to be fully realized, but NASA has taken the first of what could be many in a line of new events that expand its constituency and benefit its own operations by looking at new ways to address old problems. One positive outcome of this event was the networking that occurred between audience members and speakers, all of whom had very different, but often complementary, backgrounds.

Human Spaceflight and the Future of Space Science: A Symposium

The Universities Space Research Association (USRA) and The George Washington University's (GW's) Space Policy Institute (SPI) held a joint symposium titled "Human Spaceflight and the Future of Space Science" on January 14 at the Madison Hotel in Washington, DC. The symposium looked at the past, present, and potential future relationship and interaction between human spaceflight and space science and had a wide array of speakers from the space policy and science communities.

Dr. Scott Pace, professor at GW and director of SPI, was the emcee of the event. Dr. Pace is the former associate administrator for NASA's Program Analysis & Evaluation (PA&E) division, and took over the Institute in 2008 from John Logsdon. He opened the symposium with an overview of the current status of the human spaceflight and space science programs, saying that the projected exploration program funding has been reduced since the Exploration Systems Architecture Study (ESAS) of 2005. Dr. Pace also talked about the International Space Station (ISS), which was a major topic throughout the symposium. He said that the ISS is a political and engineering achievement and is "becoming a scientific achievement," the extent to which remains to be seen. Dr. Pace said that he finds the human vs. robots debate "an old, somewhat tired question," and that the focus should instead be on how human spaceflight can benefit science, and vice versa. The future of human spaceflight depends on whether humans can "live off the land" and operate for extended periods of time without support from Earth, and whether there are economically useful activities in space to sustain human communities. The answers to both questions are yet to be determined.

A common thread throughout the discussion was the ISS and what lies in store for thia nearly-completed outpost. The United States is looking at ending its support for the station in the 2015-2016 timeframe, but everyone at the symposium agreed that U.S. commitment to continuation and extension of the program is vitally important for many reasons. Jeff Bingham, who serves as staff on the U.S. Senate Subcommittee on Science and Space of the Committee on Commerce, Science, and Transportation, said that the nation not only has an obligation to maintain the ISS because of international commitments, but because of commitments made to the scientific community as a whole.

Talk of extending the space shuttle program beyond 2010 was addressed by some of the presenters, but the reality of the situation—production lines being shut down and workforce layoffs underway—make this unlikely.

Other presenters, such as Stephen Katz of the National Institutes of Health, and Pascale Ehrenfreund of GW, talked about biomedical research conducted on the ISS and other international efforts to conduct science in space and promote human space exploration.

Lennard Fisk of the University of Michigan, and former chair of the Space Studies Board, explained that human space exploration needs to be transformational—like Hubble, COBE, and the Apollo program—in order to receive serious funding, which will in turn make it more synergistic with space science. Dr. Fisk expressed concern that there is ample evidence that NASA is not included in the group of scientific organizations or government agencies that are perceived to be economic drivers (NASA did not receive any funding from the America COMPETES Act). He believes that the space community has not made its case effectively enough and needs to be more aggressive.

Chris Chyba from Princeton University, a member of the Review of U.S. Human Space Flight Plans Committee, was the final speaker at the event. Dr. Chyba said he is proud of the committee's report, which he believes clearly distinguished between goals and destinations—a common theme at the event. For Dr. Chyba, there is only one goal worthy of committing the large amounts of resources required for space exploration to: charting a path into the outer reaches of the solar system for humanity. He also expounded some of the benefits of the "Flexible Path" option in the report; by pursuing this exploration architecture, NASA's budget phasing is more flat and less front-loaded, because development of the Altair lunar lander would be delayed until after development of the Ares I and V rockets or suitable commercial alternatives. Dr. Chyba concluded by saying that NASA should be working on the most difficult technical challenges to space exploration and leave the simpler things (e.g., ISS resupply and low-Earth orbit activities) to the commercial space sector. Dr. Chyba suggested that the United States should either increase NASA's budget or admit that the agency's activities are being scaled back, and then heasked if there is a third option.

CONGRESSIONAL TESTIMONY

The Case for Space: Examining the Value
Before the
Senate Committee on Commerce, Science and Transportation,
Subcommittee on Science and Space
October 21, 2009

Lennard A. Fisk, vice-chair for the NRC's Committee on the Rationale and Goals of the U.S. Civil Space Program testified at the October 21, 2009, hearing on The Case for Space: Examining the Value. His prepared statement is reprinted here (without references, notes, appendices, tables, or figures). Dr. Stephen I. Katz, Director, National Institute of Arthritis and Musculoskeletal and Skin Diseases, National Institutes of Health; Dr. Scott Pace, Director, Space Policy Institute, Elliott School or International Affairs, The George Washington University; Dr. Jeanne L. Becker, Associate Director, National Space Biomedical Research Institute, and Ms Helen Greiner, CEO, The Droid Works also testified. Their prepared statements are available at http://commerce.senate.gov/public/index.cfm?fuseAction=Hearings.Hearing&Hearing_ID=242abe1f-23dc-4d67-9ff0-a9f13d00fd3b.

Lennard A. Fisk
University of Michigan

Mr. Chairman and members of the Subcommittee, I appreciate very much the opportunity to testify on the important topic of the Case for Space: Examining the Value. My name is Lennard Fisk, and I am the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan. I also served from 1987 to 1993 as the NASA Associate Administrator for Space Science and Applications, and from 2003 to 2008 as the Chair of the National Research Council Space Studies Board.

My remarks today will be based in large measure on the recent National Academies Report: *America's Future in Space: Aligning the Civil Space Program with National Needs*, which was Chaired by Gen. Les Lyles (Ret.), and for which I served as one of the Vice Chairs. My remarks, of course, are entirely my own.

I would like to talk today about civil space in its entirety, and so let me begin by defining civil space. For my purposes, civil space is all aspects of space that are not pursued for military purposes. It is the space activities of NASA and NOAA. It is all of commercial space: communication satellites, remote sensing satellites, and the many entrepreneurial activities that are now blossoming. It is also the civil use of military assets such as the commercial use of the signals from Global Positioning Satellites (GPS).

Taken in this broad context, the civil space program of the United States touches the lives of every American, each and every day. We are dependent upon GPS signals for transportation; we coordinate our telecommunication networks, internet infrastructure and electric grid and financial systems through the timing signals available from GPS. Our weather forecasts are based upon satellite observations. We have information on what is happening everywhere in the world at all times, in large measure due to satellite communications and observations.

Indeed, we can argue that the globalized world in which we live, where manufacturing is worldwide and economies are thoroughly intertwined, was able to develop because of space. The knowledge that we have about other societies and our ability to communicate instantaneously, transmitted through satellites, have given us a level of comfort to invest throughout the world. And because of this we live in a safer world, where now many nations have a vested interest in each other's success.

We also live in a world of challenges, one of the main ones being global climate change. Whether or not you agree on the causes of climate change, nonetheless we must all accept that the climate of Earth is changing, and the outstanding question is what are the regional consequences to which we must prepare to adapt. The Department of Defense has stated that global climate change is a strategic threat to the United States, in recognition that climate change in the developing world can be de-stabilizing, and lead to increased threats from, for example, terrorism.

> "Our position in the world is in part determined by what we are able to accomplish in space."

The knowledge of global climate change and its regional consequences will come uniquely from the civil space program. Comprehensive observations from the global perspective of space will be required. We may enter into treaties limiting fossil fuel emissions and other contributions to the greenhouse gases in the atmosphere. Only the global perspective of satellite observations will allow us to monitor compliance by the treaty signatories. "Trust but verify" will work equally well in climate treaties as it did for treaties limiting nuclear weapons.

We also live in a world of opportunities. We have the capabilities these days to use our civil space program to ask and to answer very fundamental questions about the universe in which we live: what is the origin, the evolution, and the destiny of our Sun, our solar system, and the universe beyond. Is there life elsewhere in the universe? Do we not also, as a rich and powerful nation, have the obligation to seek and to provide these answers on behalf of all humankind?

Our economy is reeling and the clear way forward to long-term economic growth and job creation is investments in innovative technologies. The civil space program can require the development of technologies that benefit the economic growth of the nation and it can unleash and encourage the entrepreneurial spirit on which the American economy is founded.

Our human space flight program has been able to inspire us to consider the endless opportunities of space. It also plays an important geopolitical role. Space has been and will always be the playground on which developed nations demonstrate their technological prowess. Our position in the world is in part determined by what we are able to accomplish in space.

Indeed, our entire civil space program permits us to define the image we wish to project as a nation. There are a growing number of nations with capabilities in space, and so dominance by the United States is no longer likely, nor for that matter desirable. Rather, we can use our civil space program to exert strategic leadership, in which we lead by example and in cooperation, and are valued in the world for what we are able to accomplish on behalf of all humankind.

Our civil space program can also make us more secure. We have military assets in space, which are judged to be vulnerable. It is reasonable to assume that they will be safer if space becomes a routine place for science and for commerce, just as rules-of-the-road make our oceans a lawful, not a lawless domain.

Our civil space program thus occupies a central position in the American way of life and our national goals. It assists our everyday lives; it helped create our globalized world; it satisfies our innate curiosity about the majesty of the universe; it will help determine the future of Earth; it can help drive the development of technology on which our economic future depends; it inspires us to believe that our tomorrows will be better; it is an essential component of our national image, and helps make it possible for us to be a strategic leader in a world full of challenges.

Given the centrality of the civil space program to our way of life and national goals it is somewhat troubling that we need to defend its value. I suspect this lack of appreciation results in part because space is now endemic in our society. It is so pervasive in our daily lives and national identity that we no longer fully recognize or appreciate its presence.

It is also true that we are not organized as a federal government to fully realize the benefits that our civil space program offers the nation. "National space policy is too often implemented in a stovepipe fashion that obscures the connection between space activities and other pressing needs of the nation. Consequently, the senior policy makers with broad portfolios have not been able to take the time to consider the space program in the broad national context. Rather, policies have been translated into programs by setting budget levels and then expecting agencies to manage to those budgets".

Thus, one of the key recommendations of the *America's Future in Space* report is that "the President of the United States should task senior executive branch officials to align agency and department strategies: identify gaps or shortfalls in policy coverage, policy implementation, and resource allocation; and identify new opportunities for space-based endeavors that will help to address the goals of both the U.S. civil and national security space programs".[2]

The *America's Future in Space* report further recommends that we should, through policy implementation and resource allocation, formulate and execute a civil space program in the United States that is closely aligned with and clearly serves our national needs. The service to national needs is the basis on which our national investment in civil space has and ought to be made. We have entrusted the future of our nation and our sense of wellbeing as a people to the performance of our civil space program, and we need to insure that our investments in civil space are adequate and the emphases that we place best serve our national needs.

We need a civil space program that allows us to protect the Earth and its inhabitants through the use of space research and technology; that employs the global perspective enabled by space observations to monitor climate change and test climate models, to help manage Earth resources, and mitigate risks associated with natural phenomena such as severe weather and asteroids. "NASA and NOAA should lead in the formation of an international satellite-observing architecture of monitoring global climate change and its consequences and support the research needed to interpret and understand the data in time for meaningful policy decisions".

We need a civil space program that allows us to pursue scientific inquiry and advancement of knowledge, which are fundamental to a nation's health: "the results inform and excite the public, stimulate technology development, create an interest in learning, and generally improve the capability of the nation to compete and to lead. A nation that asks question about the universe and wants to learn is a richer nation".

We need a civil space program that develops advanced technology, "engaging the best scientific and engineering talent in the country wherever it resides in universities, industry, NASA centers, or in other government laboratories". The research conducted should address the needs of the nation's entire space portfolio, both government and industry, and by doing so encourage the economic development of the nation.

We need a civil space program that actively pursues human spaceflight, "extending the human experience into new frontiers, challenging technology, bringing global prestige, and exciting the public's imagination". The criterion by which we judge our human spaceflight program should not be based upon the capabilities or aspirations of other nations. Rather, our human spaceflight program should be held to the same standard we apply to the rest of our civil space program: "It must be capable of producing transformative cultural, scientific, commercial or technical outcomes."

We need a civil space program that inspires current and future generations; "that builds upon the legacy of spectacular achievements to inspire our citizens and attracts future generations of scientists and engineers". We live in a world of many immediate concerns, from a weakened world economy, to regional conflicts and global terrorism, to threats of the consequences of climate change and limited energy sources. "A vigorous civil space program provides a strong signal that our future as a nation is promising; that life can be better; that our prospects are boundless".

We need a civil space program that allows us to pursue international cooperation in space proactively as a means to advance U.S. strategic leadership and meet national and mutual international goals. "Space is viewed by many countries of the world as global commons, a resource not owned by any one nation but crucial to the future of all humankind. Indeed, human beings around the world view space not just as a place, but rather as symbolic of the future itself. Thus, for the U.S. to exert strategic leadership there is no venue more special than space. True strategic leadership will be achieved not by dominance, which in many cases is no longer possible, but by example and in cooperation with other nations. In addition to protecting those activities in space that are judged to be essential to U.S. national interest, and for which the United States must be an undisputed leader, there should also always be concern for the larger world and for how the United States is viewed as a benevolent nation with foresight and determination to make a better world for all humankind".

We need to recognize also that there are impediments to the success of a civil space program that best serves the national needs, and these will need to be overcome. There is the impediment cited above of the lack of a cohesive and coordinated national space policy that ensures that all participants have the capabilities, whether by policy or through resource allocation, to serve their functions in this broad national endeavor. There are also impediments at the foundational level.

There is need of a competent technical workforce, "sufficient in size, talents and experience to address difficult and pressing challenges". The aerospace workforce, which serves the needs of both civil and military space, needs to be replenished, as part of a broad national effort to ensure that the nation has the technical workforce necessary to maintain our competitive position in the world and that serves the needs of our people.

There is a need for a properly sized and structured infrastructure, which makes effective use of the full capabilities that the nation has assembled to conduct its civil space program, whether in NASA centers, universities, industry, or other national laboratories. "The health of the institutional infrastructure is in question. NASA still maintains 10 large centers, as legacies of the much larger Apollo program more than 40 years ago. Responding to funding limitations and associated political pressures, NASA has elected to focus its support on its own centers. As a result, the broad national capabilities in universities and in industry have atrophied and are under utilized – in some instances imperiled – with serious consequences for U.S. capabilities for future innovation. In the case of universities, where research and education are pursued synergistically, the proper training of the aerospace workforce is in jeopardy."

There is a need for a foundation of "sustained technology advances that can provide the development of more capable, reliable, and lower-cost spacecraft and launch vehicles to achieve space program goals". "Yet, because of budgetary pressures and institutional priorities, NASA has largely abandoned its role in supporting a broad portfolio of advanced technology development for civil space applications, and the space technology base has been allowed to erode and is now deficient."

In summary, the civil space program of the United States has a central role in our society today, and our goals as a nation. This role, however, is often not recognized or appreciated, with the result that our civil space program is not adequately coordinated; nor are its priorities properly aligned with pressing national needs, with adequate resources provided; nor are its deficiencies recognized and removed. The goal of course is to reverse this situation, to construct a civil space program that is truly aligned with and capable of serving the national needs. When we do, America does have a future in space, and even more important, space can help assure America's future.

Strengthening NASA's Technology Development Programs
Before the
House Committee on Science and Technology,
Subcommittee on Space and Aeronautics
October 22, 2009

(From L to R): Dr. Robert D. Braun, Dr. Raymond S. Colladay, and Mr. Christopher Scolese

Photo courtesy of the House Committee on Science and Technology

Raymond S. Colladay, chair of the NRC's Aeronautics and Space Engineering Board and vice-chair for the NRC's Committee on the Rationale and Goals of the U.S. Civil Space Program and Robert D. Braun, co-chair of the NRC's Committee to Review the NASA Institute for Advanced Concepts testified at the October 22, 2009, hearing on Strengthening NASA's Technology Development Programs. Their prepared statements are reprinted here (without references, notes, appendices, tables, or figures). Chris Scolese, NASA, also testified. All of the prepared statements are available at http://science.house.gov/Publications/hearings_markups_details.aspx?NewsID=2640.

Raymond S. Colladay

Madam Chairwoman and members of the Subcommittee, I am pleased to appear before you today. My name is Ray Colladay and the personal views I express are shaped by my 40 years of experience in aerospace, through positions I have held in government, industry, and academia. I chair the Aeronautics and Space Engineering Board (ASEB) of the National Research Council (NRC) and also served as vice chair of the Academy funded study on ***America's Future In Space: Aligning The Civil Space Program With National Needs***. Although I have insights into NASA acquired through those and other positions, my views are my own and do not represent an official position of the NRC.

With your permission, I would like to submit my prepared testimony for the record and summarize my views for you here this morning.

In the previously mentioned NRC report on "America's Future In Space", we observed that space has become ubiquitous and permeates nearly every aspect of our daily lives. We concluded that if properly aligned and coordinated, U.S. civil space can provide technological, economic, and societal benefits that contribute to solutions to the nation's most pressing problems. The study detailed seven recommendations for U.S. leadership in space, but among the most actionable of those recommendations—one that we called "foundational" in the sense that it was among those that enabled other goals and recommendations to be met—was that NASA needs to revitalize its advanced technology development program as a priority mission area in the agency.

Because of budget pressures and institutional priorities, however, NASA has largely abandoned its role in supporting the broad portfolio of civil space applications, and the space technology base has thus been allowed to erode and is now deficient. The former NASA advanced technology development program no longer exists. Most of what remained was moved to the Constellation Program and has become oriented largely to risk reduction supporting the ongoing internal development program. Elements of that former advanced technology R&D focused on space science missions—primarily advanced instrument development—was also moved. Although it continues under the science mission directorate, and good work is being done, there is no longer the broader mandate to enhance the technology base and explore breakthrough technology that could possibly transform future science missions by influencing future requirements instead of simply responding to those already established.

The NRC report observed that future U.S. leadership in space requires a foundation of sustained technology advances that can enable the development of more capable, reliable, and lower-cost spacecraft and launch vehicles to achieve space program goals. A strong advanced technology development foundation is needed also to enhance technology readiness of new missions, mitigate their technological risks, improve the quality of cost estimates, and thereby contribute to better overall mission cost management. Space research and development efforts can take advantage of advances from other fields—and can contribute back to those fields. For example, civil space programs can benefit from and contribute to the state of the art in advanced materials, computational design and modeling, batteries and other energy storage devices, fuel-cell and compact nuclear power systems, fault-tolerant electronics and software, optics, and robotics. This scientific synergy extends the ability to accomplish more capable and dramatic missions in space, as well as to contribute to broader national interests driving innovation in other areas of terrestrial application. The unique challenges of the space environment make demands on technology in ways that often accelerate the development pace and advance understanding of the foundations of technologies. The responsibility to provide for this advanced technology base for civil space activities rests with NASA, in partnership with universities, other government agencies, and industry. The "customers" for the products of technology are NASA, NOAA, industry, and military space programs in which multiple-use technology is applicable.

To fulfill NASA's broader mandate, the study concluded that an independent advanced technology development effort is required, much like that accomplished by DARPA in the DOD, focused not so much on technology that today's program managers require, but on what future program managers would wish they could have if they knew they needed it, or would want if they knew they could have it. This effort should engage the best science and engineering talent in the country wherever it resides in universities, industry, NASA centers, or other government laboratories independent of pressures to sustain competency at the NASA centers. A DARPA-like organization established within NASA should report to NASA's Administrator, be independent of ongoing NASA development programs, and focus on supporting the broad civil space portfolio through the competitive funding of world-class technology and innovation projects at universities, industry, federally-funded research and development centers, government research laboratories, and NASA centers. The responsibilities of the organization should be similar to those of NASA's aeronautics research in the sense that the research activities should be supportive of the needs of the private sector as well as the government—a mission well understood and supported by NASA going back to its predecessor, NACA.

Establishing an independent organization focused on broadly enhancing the technology base for civil and commercial space does not mean the development programs and operational mission areas of NASA do not need their own technology research and development resources to mature technology ready for transition and for risk reduction. Furthermore, a technology management process is needed that draws the interests of all stakeholders to common ground to assure the investment in technology is relevant to the needs of the eventual users and that a plan exists for its transition. This process creates a healthy tension between technology push and user pull.

The DARPA-like reference is not to be taken too literally, since what works well in the Department of Defense needs to be adapted to the NASA culture. But the reason for the reference is to address the need for an advanced technology mission to be given priority, be organizationally independent, be authorized to pursue technical excellence and research quality wherever it resides relieved of NASA institutional requirements, and be encouraged to promote and sponsor transformational, game-changing innovation that is not necessarily formally tied to existing, well-defined requirements.

The country expects NASA to be a leader pushing the frontiers of air and space applications and missions as called for in the Space Act. But to do so, they need to replenish the underpinning technology that makes it possible. I believe it is time to make technology research and development an explicit priority as part of the agency's broader mission.

Thank you. That completes my prepared remarks and I would be pleased to take questions you may have.

Dr. Robert D. Braun
Georgia Institute of Technology

Madame Chairwoman, Ranking Member Olson and members of the Subcommittee, thank you for the honor of appearing before you today to discuss approaches to strengthen NASA's advanced concept and technology development programs. My name is Robert D. Braun. The views I express today have been shaped through a twenty-two year aerospace engineering career in government and academia. For sixteen years, I served on the technical staff of the NASA Langley Research Center. At NASA, I developed advanced space exploration concepts, managed multiple technology development efforts, and contributed to the design, development, test and operation of several robotic Mars flight systems. For the past six years, I have served on the faculty of the Daniel Guggenheim School of Aerospace Engineering at the Georgia Institute of Technology. As Director of Georgia Tech's Space Systems Design Laboratory, I lead an active research and educational program focused on the design of advanced flight systems and technologies for planetary exploration. The advanced space systems concept and technology maturation skills being developed by the undergraduate and graduate students at Georgia Tech are of significant interest to NASA, the U.S. Air Force, DARPA, our national labs, industry, and others in academia. It gives me great pride to work closely with these students, who are on their way to becoming the space systems engineers of our nation's future.

Today, I speak to you as the co-chair of the National Research Council's Committee to Review the NASA Institute for Advanced Concepts, which recently released our report ***Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts***. The committee's twelve members were chosen by the NRC for their experience with advanced space and aeronautical concepts and their insight into cogent approaches to spark scientific innovation and creativity. They represent a diverse cross-section of aerospace sector experience, including NASA, DARPA, the SETI Institute, industry, and academia. The committee was co-chaired by Dianne S. Wiley, a Technical Fellow at Boeing Phantom Works and myself. I must say that it was a pleasure to work through the NRC with this talented and experienced group of people.

As the first question posed by the subcommittee, I would like to begin by summarizing our committee report.

Fostering Visions of the Future: A Review of the NASA Institute for Advanced Concepts

NASA established the NASA Institute for Advanced Concepts (NIAC) in 1998 to provide an independent, open forum for the external analysis and definition of revolutionary space and aeronautics concepts to complement the advanced concepts activities conducted within the Agency. Funded at approximately $4 million per year (roughly 0.02% of NASA's budget), NIAC received a total of $36.2 million in NASA funding during the 9 years of its existence. As directed by the NASA SOW, NIAC focused on revolutionary advanced concept studies that could impact a NASA mission 10 to 40 years in the future. NIAC inspired an atmosphere of innovation that stretched the imagination and encouraged creativity. In response to its yearly solicitations, NIAC received a total of 1309 proposals, and made 126 Phase I awards and 42 Phase II awards, primarily to small businesses and universities, but also to large businesses and national laboratories. To reduce costs and maximize public accessibility, NIAC utilized an open, web-based environment to conduct solicitations, perform peer review, administer grant awards, and publicize its activities. NIAC received an "Excellent" performance rating in each NASA annual review held. Many NIAC grantees went on to receive additional funding for continued development of their concept from NASA, other government agencies or private industry. In addition to developing revolutionary concepts, NIAC placed an emphasis on science and engineering education as well as public outreach. At its inception, NIAC was envisioned as a crosscutting program reporting to the Agency's Chief Technologist. In 2004, when the NASA Office of Aerospace Technology was dissolved, NIAC program management was transferred into the NASA Exploration Systems Mission Directorate. In 2007, NIAC was terminated.

In 2008, Congress directed the National Research Council (NRC) to conduct a review of the effectiveness of NIAC and to make recommendations concerning the importance of such a program to NASA and to the nation. Our committee was given the following statement of task:

1. Evaluate NIAC's effectiveness in meeting its mission.
2. Evaluate the method by which grantees were selected.
3. Make recommendations on whether NIAC or a successor entity should be funded by the Federal government.
4. Make recommendations as to how the Federal Government in general and NASA in particular should solicit and infuse advanced concepts into its future systems.

In evaluating NIAC's performance, the committee addressed the following questions:

1. To what extent were the NIAC-sponsored advanced concept studies innovative and technically competent?
2. How effective was NIAC in infusing advanced concepts into NASA's strategic vision, future mission plans, and technology development programs?
3. How relevant were these studies to the aerospace sector at large?
4. How well did NIAC leverage potential partnerships or cost-sharing arrangements?
5. What potential approaches could NASA pursue in the future to generate advanced concepts either internally or from external sources of innovation?

The key findings and recommendations from our report can be summarized in the following seven statements:

1) NIAC met its mission and accomplished its stated goals. The committee found that NIAC's approach to implementing its functions successfully met NASA-defined objectives, resulted in a cost-effective and timely execution of advanced concept studies, afforded an opportunity for external input of new ideas to the agency, and subsequently provided broad public exposure of NASA programs. NIAC was successful in encouraging and supporting a wide community of innovators from diverse disciplines and institutions as evidenced by receipt of 1309 proposals in its 9-year lifetime. The 126 NIAC Phase I studies were led by a total of 109 distinct principal investigators, each of whom led a research team of 3-10 personnel, often across multiple organizations. The majority of the NIAC-supported efforts were highly innovative. Many were successful in pushing the state of the art. Overall, the efforts supported produced results commensurate with the funding and risk involved.

2) NIAC had infusion successes and challenges. One important NIAC performance metric defined in the NASA SOW was achievement of 5 to 10 percent infusion of NIAC-developed Phase II concepts into NASA's long-term plans. One way to gauge such infusion is to look at the receipt of post-NIAC funding for the continued development of a NIAC-funded concept. The committee found that 14 NIAC Phase I and Phase II projects, which were awarded $7 million by NIAC, received an additional $23.8 million in funding from a wide range of organizations, demonstrating the significance of the nation's investment in these NIAC advanced concepts. NIAC matured 12 of the 42 Phase II advanced concepts (29 percent), as measured by receipt of post-NIAC funding. In fact, 9 of these (21 percent) received post-NIAC funding from NASA itself. Over the long term, the ultimate criterion for NIAC success is the number of funded projects that make their way into the relevant NASA mission directorate decadal survey, strategic plan, or mission stream. The committee found that three NIAC Phase II efforts (7 percent of the Phase II awards) appear to have impacted NASA's long-term plans. Of significance, two of these efforts have either already been incorporated or are currently under consideration by the NRC Astronomy and Astrophysics Decadal Survey as future NASA missions: the MAXIM x-ray interferometry concept for black hole imaging and the New Worlds Observer constellation for exoplanet discovery. Considering the 40-year planning horizon of NIAC activities coupled with the 9-year existence of NIAC, the committee believes it is likely that the number of NIAC Phase II projects considered for NASA missions will continue to increase over time.

On the other hand, by design, the maturity of NIAC Phase II products was such that a substantial additional infusion of resources was needed before these advanced concepts could be deemed technically viable for implementation as part of a future NASA mission or flight program. The committee found that this technology readiness immaturity created infusion difficulties for the NIAC program and innovators, causing promising ideas to wither on the vine.

3) NASA and the nation need a NIAC-like organization. NASA is now an agency largely oriented toward flight-system development and operations. Priorities have thus diminished within NASA for long-range research and development efforts. At present, there is no NASA organization responsible for solicitation, evaluation, and maturation of advanced concepts (defined as those at technology readiness level one or two) or responsible for subsequent infusion of worthy concepts into NASA planning and development activities. Over the past few years, such NASA efforts have been ad hoc, lacking in long-term stability, and not integrated into the agency's strategic planning process. Managed in this fashion, advanced concept efforts will rarely produce mature products an dthe agency is at risk of driving away many of its most creative personnel. Our committee believes that NASA and the nation would be well served by maintaining a mechanism to investigate visionary, far-reaching advanced concepts as part of NASA's mission. Concepts deemed feasible could be used to inform NASA's strategic planning process. Long-term, these concepts and technologies offer the potential for dramatic improvements in performance and/or cost of future aeronautical and space systems. As such, the committee recommends that NASA should reestablish a NIAC-like entity, referred to in our report as NIAC2, to seek out visionary, far-reaching, advanced concepts with the potential of significant benefit to accomplishing NASA's charter and to begin the process of maturing these advanced concepts for infusion into NASA's missions. The existence of such an organization would also demonstrate that NASA continues to be a driver of innovation and technological competitiveness, potentially serving as a critical element of NASA's public and educational value to the nation.

4) The original NASA implementation of NIAC as an external organization managed above and across the mission directorates was effective. When it was initially formed, NIAC was managed by a high-level agency executive concerned with the objectives and needs of all NASA enterprises and missions. The committee found that NIAC was most successful as a program with crosscutting applicability to NASA's enterprises and missions. When it was transferred to a mission-specific directorate, NIAC lost its alignment with sponsor objectives and priorities. To allow for sustained implementation of NIAC2 infusion objectives, the committee recommends that NIAC2 report to the Office of the Administrator, be outside mission directorates, and be chartered to address NASA-wide mission and technology needs. To increase NIAC2's relevance, NASA mission directorates should contribute thematic areas for consideration in the proposal solicitation process. The committee also recommends that this NIAC2 organization be funded and administered separately from NASA development programs, mission directorates, and institutional constraints. Future NIAC2 proposal opportunities should continue to be managed and peer-reviewed outside the agency.

5) NIAC2 modifications should be made to improve effectiveness. While NIAC's internet-based technical review and management processes were found to be effective and should be continued in NIAC2, the committee found a few policies that may have hastened NIAC's demise. Key among these was (1) the exclusive focus on revolutionary advanced concepts, (2) the exclusion of NASA personnel from participation in NIAC awards or research teams, and (3) the immaturity of NIAC Phase II products relative to that required for implementation as part of a future NASA mission or flight program.

By definition, visionary advanced concepts will not be near-term. However, in our committee discussions, it was felt that NIAC's complete focus on revolutionary concepts (as directed in its NASA SOW) was too long-term, creating a cultural mismatch between the NIAC products and its mission-focused sponsors and causing infusion difficulties for the NIAC innovators. As such, the committee recommends that the key selection requirement for NIAC2 proposal opportunities be that the concept is scientifically and/or technically innovative and has the potential to provide major benefit to a future NASA mission of 10 years and beyond. While 10 years and beyond includes concepts that could be 40 years or farther in the future, the committee felt that these modifications in focus would likely result in NIAC2 efforts with a higher probability of infusion into NASA's strategic planning process.

NIAC was formed to provide an independent, open forum for the external analysis and definition of space and aeronautics advanced concepts to complement the advanced concepts activities conducted within NASA; hence, NIAC solicitations were closed to NASA participants. However, NIAC was formed at a time when there was adequate funding internal to NASA for development of novel, long-term ideas. As internal NASA funding for advanced concepts and technology diminished or became more focused on flight-system development and operations, the cultural disconnect between the development activities internal and external to the agency grew, and transitioning of NIAC concepts to the NASA mission directorates became more difficult. The committee recommends that future NIAC2 proposal opportunities be open to principal investigators or teams both internal and external to NASA.

In addition, the committee believes that the potential for receipt of a NIAC2 Phase III award is needed to aid the transition of the most highly promising projects. Therefore, the committee recommends that future NIAC2 proposal opportunities include the potential selection of a small number of Phase III "proof of concept" awards for up to $5 million each over as much as 4 years to demonstrate and resolve fundamental feasibility issues and that such awards be selected jointly by NIAC2 and NASA management.

6) NASA modifications should be made to improve effectiveness. The lack of a NASA interface to receive the hand-off of promising projects was a persistent NIAC challenge. To improve the manner in which advanced concepts are infused into its future systems and to build a culture that continuously strives to advance technology, the committee recommends that NASA consider reestablishing an aeronautics and space systems technology development enterprise. Such an organization would serve to preserve the leadership role of the United States in aeronautical and space systems technology. Its NIAC2-oriented purpose would be to provide maturation opportunities and agency expertise for visionary, far-reaching concepts and technologies. NASA's considerations for such an enterprise should include implications for the agency's strategic plan, effective organizational approaches, resource distributions, field center foci, and mission selection process. Increased participation of NASA field center personnel, beyond review and management functions, should also significantly enhance advanced concept maturation and infusion into NASA mission planning. The committee also recommends identification of center technical champions and provision for the technical participation of NASA field center personnel in NIAC2 efforts. Participation of NASA personnel is expected to increase as NIAC2 projects mature.

7) The budget requirement for a strong advanced concepts development activity reaches a steady-state value of approximately $10M per year. Our committee believes that the NIAC was generally funded appropriately (approximately $4M/year) for its stated Phase I and Phase II objectives. We believe that NIAC2 proposal opportunities should be defined as follows: Phase I up to $100,000 each for 1 year; Phase II, up to $500,000 each for 2 years; Phase III proof-of-concept awards for up to $5 million each over as much as 4 years. Clearly, the number of such awards could be used as a control on the overall program budget. For example, in the first year of NIAC2, perhaps a dozen Phase I awards would be made for $1.2M, plus administrative costs. Including 4 Phase II awards in the following year would push the required yearly budget to approximately $2.2M (plus administrative costs). As a strawman, I note that if NIAC2 funded 12 Phase I awards, 4 Phase II awards, and 1 Phase III award in each subsequent year, the budget requirement would increase by $1.25M each year until reaching a steady-state value of $8.2M in year six and beyond (plus administrative costs). In a strategy like this, the overall program budget is largely dependent on selection of the Phase III awards. If NASA saw value in the potential offered by multiple Phase III proposals, additional funds could be secured. If funding were tight in a given year, no Phase III awards would be made.

NIAC2 funding decisions should be made within the context of a well-funded NASA aeronautics and space systems technology enterprise that is both actively seeking advanced system concepts and maturing the requisite technological solutions. Large-scale technology development aspects of this enterprise were beyond the committee's charter, and would require considerably more funding than the $10M proposed for NIAC2. These larger funding issues are addressed in my response to your next question.

In addressing the subcommittee's remaining questions, I am guided by my personal experience in NASA and academia. Although the NC NIAC committee's discussions touched on these topics, our committee was not specifically tasked to address these broader subjects.

In response to the second question posed by the subcommittee, I would like to define the scope of a broadly focused long-term program dedicated to stimulate innovation and develop new concepts and capabilities, and then describe the results our nation should expect from such a program.

Three Technology Development Classes and the Need for a Strengthened Capability-Based Technology Development Effort within NASA

In my experience, there are three general classes of technology development programs: mission-focused (near-term), discipline-based (long-term), and capability-based (mid-range). A NASA strongly positioned for the future should sponsor a blend of these three technology development classes, strategically guided by the results of a continuously engaged advanced concepts program. It is in this way that an advanced concepts program can be used to inform an organization's strategic planning process and provide value to its technology investment decisions. The success of such an enterprise will clearly be dependent on the group of program managers and systems engineers making technology readiness assessment and technology investment decisions for the agency. Passionate, hard-charging systems engineers and program managers who remain objectively focused on the long-term development needs of the agency, independent of the agency's institutional constraints, and out of the proverbial technology sandbox will be required. A series of competitively awarded activities spanning near-term, mid-term and long-term aeronautics and space systems needs is likely the best means of implementing a successful technology development program. Competitive awards should be made based on an objective assessment of the agency's strategic need, the proposed technical scope and product realism.

Mission-focused technology programs abound in most current large NASA programs. Consider, for example, NASA's human spaceflight program. In development of the Constellation architecture, priority was given to near-term systems with the goal of an early initial operational capability – existing technology with low risk was the Constellation mantra. In fact, funding from a wide range of NASA advanced technology programs was redirected to enable this capability. However, even with its near-term focus and budgetary challenges, the Constellation program required and funded a small number of mission-focused technologies to enable qualification of the key technologies required for mission success. These mission-focused technology programs include a lunar-return capable heatshield, an autonomous landing and hazard avoidance system for lunar landing operations, and lunar in-situ resource utilization. Without such technological advances, NASA's current approach to returning humans to the Moon would be dramatically impacted. Similar mission-focused technology investments have allowed NASA's robotic exploration program to pursue advanced science missions like the Mars Science Laboratory and Webb Space Telescope. Clearly, these are important investments that require NASA funding. However, these mission-focused activities are not the only technology investments that an agency that prides itself on innovation and pushing-the-boundary should pursue.

Within NASA, the ARMD Fundamental Aeronautics program is the only present program of which I am aware that is pursuing discipline-based technological solutions. Longer term by nature and generally funded at a much lower level, these technology advances are often pursued with the promise of enabling dramatic performance improvements in one or more aerospace disciplines, and the potential for major system advances across multiple future programs. While ARMD funding is largely directed internal to NASA and its aeronautics challenges, examples of possible discipline-based technology investments include laminar flow control technology, high-temperature materials and structures, hypersonic airbreathing propulsion, advanced in-space propulsion, robust navigation and control algorithms, high-efficiency solar power systems, radiation protection systems, and inflatable structures. In addition, NASA can now offer unique, discipline-based microgravity research opportunities through effective utilization of the International Space Station.

The United States boasts a tremendously successful robotic Mars program. Continuous orbital observations of the Mars surface have been made for more than a decade and six robotic systems have now been placed on the surface of Mars. While each of these six landed missions has been an incredible technological accomplishment in itself, these robotic systems have each landed less than 0.6 metric tons within landing footprints on the order of hundreds of kilometers. At present, robotic exploration systems engineers are struggling with the challenges of increasing landed mass capability to just 1 metric ton (less than half the Earth weight of a 2009 Ford Explorer) while improving landed accuracy to 10 kilometers for the Mars Science Laboratory project. Meanwhile, the planning of subsequent robotic exploration missions under consideration for the 2020 decade may require several metric tons in landed mass capability and current plans for human exploration of Mars call for the landing of 40-80 metric ton surface elements within close proximity (tens of meters) of pre-positioned robotic assets. These future mission requirements cannot be met with NASA's present suite of entry, descent and landing technologies and are one reason that human Mars exploration is viewed as a "bridge too far" by many in the aerospace and public policy communities. However, analysis suggests that there are a handful of promising entry, descent and landing capabilities that may prove feasible for these larger landed systems, enabling future Mars exploration concepts of which today we can only dream. These technologies are termed capabilities because these same general systems may also prove advantageous for Earth-return missions or missions to other planets – such developments are not specific to a single mission. Additional capability-focused technology needs abound in deep space exploration, astrophysics, aeronautics, and Earth science. In each case, NASA technology investment is critical – for without such an investment, these future missions will simply not occur.

Strategic assessment of our nation's future spaceflight technology needs was performed by both the Aldridge Commission in 2004 and the Augustine Commission in 2009. Each commission concluded that successful development of a set of enabling technologies (or capabilities) is critical to attainment of human and robotic exploration objectives within reasonable schedule and affordable cost. The NASA Authorization Act of 2008 furthered this sentiment by codifying it into law. Section 405 of this Act states, "*A robust program of long-term exploration-related research and development will be essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system.*" This Act further states that this program shall not be tied to specific flight projects. I strongly agree with the capability-based technology sentiment expressed by these two Presidential Commissions and the NASA Authorization Act of 2008.

While mid-term, capability-based technology investments are perhaps the most critical for a forward-looking Agency like NASA; within NASA today, this type of technology investment is minimal. NASA presently invests approximately $1.35B on a range of near-term, mid-range and long-term technologies. Approximately two-thirds of this investment is directed towards near-term mission-focused technologies that are strongly coupled to NASA's existing programs. This allocation leaves approximately $0.45B (less than 3% of NASA's total budget) for capability-based technology development and discipline-based fundamental research that is not tied to existing program requirements. However, at present, a majority of these remaining funds are allocated to the longer-term ARMD Fundamental Aeronautics program, leaving little mid-range capability-based technology investment.

Anticipated Results from a Broadly Focused Long-Term NASA Program to Develop Advanced Concepts and their Associated Technologies

Many positive outcomes are likely from a long-term, broadly focused NASA advanced concepts and technology development program that include mission-focused, capability-based and discipline-based components. Chief among these consequences is the provision of a more vital and productive aeronautics and space future than our country has today. Each year, in the first lecture of my freshman *Introduction to Aerospace Engineering* class, I share with these recent high-school graduates a list of accomplishments that I believe our nation's civil aeronautics and space program is capable of achieving in my lifetime:

Ten Anticipated Paradigm-Changing Civil Aeronautics and Space Advances

1. Quantify Causes, Trends and Effects of Long-Term Earth Climate Change
2. Accurately Forecast the Emergence of Major Storms and Natural Disasters
3. Develop Efficient Space-Based Energy Sources
4. Prepare an Asteroid Defense
5. Identify Life Elsewhere in our Solar System
6. Identify Earth-like Worlds Around Other Stars
7. Initiate Interstellar Robotic Exploration
8. Achieve Reliable Commercial Low-Earth Orbit Transportation
9. Achieve Affordable Supersonic Business Travel
10. Achieve Permanent Human Presence Beyond the Cradle of Earth

Advances of this type are more than a single professor's dream – they are a spark to a technology-based economy, an international symbol of our country's scientific and technological leadership, and a component of the remedy to our nation's scientific and mathematics literacy challenges. I genuinely believe that game-changers like these are within our nation's grasp. Capability-based technology investment, focused leadership and stability of purpose are the only elements holding us back. Landing humans on Mars requires an investment in advanced technology, as does developing a telescope capable of detecting Earth-size planets around other stars, flying a new generation of human-rated launch systems, or identifying life elsewhere in our solar system. Our nation needs to dream big, and large goals, like these, are precisely the kind of objectives that our nation has come to expect of NASA. It is equally clear that in the absence of sustained, broad-based technology investments, the United States will not continue to make significant advances in aeronautics, space, and the associated sectors of our society. Investments of this scale will not be without cost. I believe that our nation would be well served by investing at least 10% of NASA's budget in support of the technologies required to dramatically advance entirely new aeronautics and space endeavors (in contrast to an investment of less than 3% today).

In this same class, I often ask the students why they are choosing to become aerospace engineers. Generally speaking, these 18-year olds simply want to contribute to humanity's future by solving our nation's grand technological challenges. They want to work with others (and in organizations) who feel the same way. As such, a well managed, broad-based advanced concepts and technology development program can serve as a catalyst to revitalize our nation's aerospace workforce with the best and brightest of tomorrow. Such an organization can also serve to demonstrate that NASA continues to be a driver of scientific innovation, engineering creativity and technological competitiveness for our country and around the world.

NASA technology innovation efforts are also bound to stimulate the university and commercial sectors, create new business and increase the number of high-tech jobs across our nation. As a small-scale example, NIAC efforts contributed to the launch of a new business division within ENSCO and two entirely new businesses (Space Elevator: Black Line Ascension and Liftport).

In response to the third question posed by the subcommittee, I would like to briefly discuss the additional uncertainty and risk associated with developing new concepts and technologies within NASA's flight projects.

Technology Development within NASA's Missions Contribute Significant Cost and Schedule Risk

Implementation of NASA space flight missions is fraught with complex systems engineering challenges due to the extreme environment in which these systems must reliably operate. Completing a spaceflight mission within its established budget and schedule constraints is one of the most difficult undertakings in the engineering field. As such, I have great respect for those within NASA who have succeeded in these endeavors. These missions demand a focus on technical excellence across the organization, a systems engineering approach to project implementation, technical insight and crisp decision-making from project managers, clear communication across the organization, and early risk identification, prioritization, and mitigation. These implementation challenges are difficult to manage, requiring rigorous project management attention. In addition, trades between performance, cost, schedule and risk are generally constrained by program-level decisions and public policy decisions made outside the project's control. In my view, adding requirements for technology development to a flight project in the implementation phase is inherently risky and a poor program management practice.

In March 2009, in testimony presented before this committee entitled, *NASA Projects Need More Disciplined Oversight and Management to Address Key Challenges,* a GAO representative described her analysis of thirteen NASA flight projects in the implementation phase. In this project phase, systems design is completed, scientific instruments are integrated, and the flight system is fabricated and prepared for launch. Prior to entering the implementation phase, it is standard NASA practice to have finalized requirements, concepts and technologies and establish a baseline project plan. Ten of the thirteen NASA projects in the implementation phase assessed by the GAO experienced significant cost and/or schedule growth from their project baselines. Of the five causes of cost and/or schedule growth cited by the GAO, two issues pertain directly to technology development risk: technology immaturity and modifications required to previously considered heritage items. The common symptom of these two causes is a technological readiness considerably below that estimated by the project. The GAO report concludes, "Simply put, projects that start with mature technologies experience less cost growth than those that start with immature technologies." I fully agree with this statement.

NASA also knows this lesson. In fact, NASA requires all technologies used in its competitive missions to be at a technology readiness level of six (system/subsystem model or prototype demonstration in a relevant environment) or higher by the beginning of the project implementation phase. In a competitive proposal, failure to have such a technology maturation plan is generally cited as a major weakness. As such, few, if any, competed missions begin implementation while still developing technology. However, this same approach is not generally applied to NASA's larger space flight programs, which often rely on large technology advancements as part of project implementation due to the significant performance gains that they are attempting to achieve. As a result, large, non-competed projects tend to encounter significant cost overruns and/or schedule delays as a result of technology risk. Insisting on an adequate formulation phase in which this technology risk is firmly retired, before committing project implementation funding, is the most straightforward means for reducing the cost and schedule risk of these large NASA missions.

In response to the fourth question posed by the subcommittee, I would like to briefly discuss the time horizons required for the development of advanced concept and technology development programs.

Time Horizons on Advanced Concept and Technology Development Programs

A long-term, broadly focused NASA advanced concepts and technology development enterprise should span multiple timeframes in which the maturation time required for a given technology should be coupled to the agency's strategic planning process through ongoing NIAC2 advanced concept studies. Within this enterprise, one can envision a blend of technology development timeframes spanning 2-5 years for mission-focused technology (moderate $ investment), 5-15 years for capability-based technology (large $ investment), and 15-40 years for discipline-based technology (modest $ investment). Competitive awards across these technology classes should be made on a 2-3 year cycle depending on the milestones achieved and funding availability. Technology project development lifecycles spanning 2-5 years are anticipated. In this scenario, the technology development enterprise should partner with NASA's existing flight programs such that the mission-focused technologies it funds benefit from a 50% cost contribution from the relevant mission directorate. This strategy should allow for capability-based technologies, which are not tied to NASA's existing missions, to dominate the investment portfolio of the technology development enterprise. This emphasis on capability-based technology is absent in NASA today. A broad range of discipline-based investments should also be funded at a lower level.

Use of NIAC2 as a long-term asset to inform NASA's strategic planning process is a key component of this plan. NIAC2 can look out for advanced concepts beyond the current development programs. It can work on the edges where requirements are not yet known, focused on what program managers would want if they knew that they needed it. However, it is also clear that for this independent organization that nurtures technology push to succeed, it must be partnered with a substantive NASA enterprise of technology pull, managed at the agency-level with input from the existing mission directorates.

Summary

There is little capability-based technology development within NASA today and no NASA organization responsible for solicitation, evaluation, and maturation of advanced concepts or responsible for subsequent infusion of worthy concepts into NASA's strategic planning process. In my view, this is not acceptable for an agency whose purpose includes demonstrating this nation's scientific and technological prowess, or one that is trying to inspire the next generation of engineers and scientists. A technology-poor NASA greatly hampers our aeronautics and space flight development programs. We cannot continue to rely on 1970's-era technology to land systems on Mars, particularly if we want to build towards eventual human exploration. We cannot continue to explore the solar system robotically without advanced in-space propulsion and atmospheric flight technologies as part of our future mission portfolio. We cannot plan a sustainable human exploration program without strong technology leverage. Strategic assessment of our nation's future spaceflight technology needs was performed by both the Aldridge Commission in 2004 and the Augustine Commission in 2009. Each commission concluded that successful development of a set of enabling technologies (or capabilities) was critical to attainment of space exploration objectives within a reasonable schedule and affordable cost. The NASA Authorization Act of 2008 furthered this sentiment by codifying it into law. Based on these inputs, I suggest NASA establish a formal enterprise to continuously evaluate, prioritize, and mature these technologies in the relevant environments. Within this enterprise, a blend of technology development activities spanning mission-focused technology (2-5 year maturation timeframe, moderate $ investment), capability-based technology (5-15 year maturation timeframe, large $ investment), and discipline-based technology (15-40 year maturation timeframe, modest $ investment) should be pursued.

Our nation would be well served by investing at least 10% of NASA's budget in support of the technologies required to dramatically advance entirely new aeronautics and space endeavors (in contrast to an investment of less than 3% today). This investment would include a small amount for advanced concepts so difficult to achieve that their chance of individual success within a decade is less than 10%, yet concepts so innovative that their success could serve as game-changers for this vital, national industry. Our nation needs to dream big, and large goals are precisely what our nation has come to expect of NASA. Major breakthroughs are needed to address our society's energy, health, transportation, and environment challenges. While NASA investments alone will not solve these grand challenges, NASA has proven to have a unique ability to attract and motivate many of the country's best young minds into educational programs and careers in engineering and science. Although it is not possible to predict which advanced aerospace concepts will produce paradigm-shifting results, it is certainly true that, in the absence of research on such concepts, the United States will not make revolutionary technological advances in aeronautics and space and long-term societal goals in these and related areas will remain beyond our reach.

STAFF NEWS

AWARDS

We are happy to announce that several of our staff members have been honored with awards in 2009. The Division on Engineering and Physical Sciences (DEPS) announced their 2009 staff awards: two current SSB staff members, Carmela Chamberlain and Brant Sponberg, and several friends of the SSB from the Board on Physics and Astronomy (Michael Moloney, Jim Lancaster, Roc Riemer, David Lang, Caryn Knutsen, and Lavita Coates-Fogle) received the Team Award for their work on the Astro 2010 Jamboree, a meeting of the Astronomy and Astrophysics decadal survey that included the steering committee and all nine panels. Another friend of the SSB, Andrea Rebholz of the Aeronautics and Space Engineering Board was awarded the DEPS Inspiration Award.

NEW FACES

Abigail Sheffer, our Christine Mirzayan Fellow, finished her fellowship in late November and joined the SSB as an associate program officer on December 5. She is currently working with David Smith and Dwayne Day on the Planetary Science Decadal Survey. Dr. Sheffer earned a Ph.D. in planetary science from the Lunar and Planetary Laboratory at the University of Arizona and a B.A. in geosciences from Princeton University. Her doctoral research explored the relationship between the high pressures and temperatures caused by meteorite impacts and the extremely reduced chemistry of impact glasses such as tektites and lunar regolith agglutinates.

DEPARTURES

Angie Wolfgang *completed her assignment with the SSB as a Summer 2009 Lloyd V. Berkner Space Policy Intern in August. Her reflections on her experience with the SSB appear below.*

I first heard about the Lloyd V. Berkner Space Policy Internship in an American Astronomical Society e-newsletter soon after I became a AAS member during my junior year of college. Immediately the internship piqued my interest: here was a unique opportunity to explore a career path not traditionally advertised as an option for undergraduate physics majors. I had only recently recognized my deep passion for science education and communication while doing some soul-searching about my plans to continue on the academic "default" path of graduate school, and so I was actively searching for occupations that wouldenable the pursuit of these newly discovered interests. Fortunately, as I read further into the internship description and about the Space Studies Board and the National Academies as a whole, I realized that a career in science policy provides innumerable opportunities to communicate the importance of science and its role in national issues to the people who would make decisions affecting millions of people. Here was the difference a science advocate could make in Washington. I resolved not to let the opportunity to further investigate science policy as a career pass me by.

And I was far from disappointed. Through the SSB I attended several congressional hearings on NASA's budget, a NASA Advisory Council subcommittee meeting reviewing the Planetary Science Division's missions, two public meetings of the Augustine commission deciding the future of the human space flight program, and SSB report briefings with the Office of Science and Technology Policy. Through these first-hand experiences, along with the plethora of stories and lessons on Washington politics from the SSB staff members, I received a rich insider look into the challenges, rewards, and day-to-day demands of a career in space policy. For a science major unversed in the realities of politics, this internship affords an extremely valuable education in the processes of government—and for me, it reinforced my interest in science policy as a possible career choice.

Besides learning how NASA really operates and how Congress really makes decisions, however, I also learned a substantial amount about my own field and the scientific community I would become a part of in the fall at graduate school. Before I had even arrived in Washington DC, I was recruited to provide a helping hand at the June Astro2010 Program Priority Panel meetings in Long Beach, CA. When I was not manning the registration table or providing logistical support to the panels, I was listening to the presentations, absorbing as much information as I could on the latest scientific and technological advances in astronomy, and listening intently to the panel discussions to gain insight on the most pressing astronomical issues and questions. This opportunity to hear from and connect with experts in my field drastically sped up the process of becoming integrated in the astronomy community as a fellow informed scientist. As my undergraduate research advisor remarked with surprise when he saw me in one of the closed sessions, "Well Angie, you certainly are getting an inside look on what really goes on in astronomy!"

All told, my summer at the Space Studies Board was one of the most positive internship experiences I've ever had. In attending space policy events in Washington, writing summaries of them for the SSB, preparing slates of candidate committee members, compiling background information for the panels, editing reports, and helping nearly a dozen panel meetings run smoothly during the busy time of decadal surveys, I felt like I substantially contributed to the Board's activities. The SSB staff fully integrated the interns in the workings of the Board, teaching us all the background information we needed to know and including us in more informal discussions around the lunch table. I learned so much during my time at the SSB that I have a hard time remembering what it was like to not understand the politics of space! I know that I will certainly continue to draw on this knowledge throughout my graduate school career, and that I will strongly consider space policy as a viable career option once my time comes to graduate in another 5 years. Thank you, SSB, for a wonderful summer internship experience!

Elena Amador *completed her assignment with the SSB as an Autumn 2009 Lloyd V. Berkner Space Policy Intern in December. Her reflections on her experience with the SSB appear below.*

My internship with the Space Studies Board this fall semester has been a wonderful experience. As a planetary science student, I came to Washington, DC, knowing next to nothing about space policy, or politics in general. My hope was to learn has much as possible about how important decisions in the world of planetary sciences were made, how priorities were set, and what people meant when they spoke of "the politics behind NASA."

I was not been disappointed. I have been fortunate enough to attend multiple panel sessions for the Planetary Science Decadal Survey, congressional hearings on human spaceflight, and committee meetings on interagency cooperation in space and Earth sciences. The Space Studies Board has been an excellent place to learn about the world of science policy, with so many opportunities to take part in projects that range across the spectrum of science—from aeronautics to Earth sciences.

Washington, DC, has been the perfect setting for this internship. When I wasn't working and learning new things at the National Academies, I was able to explore all the great museums, agencies, monuments, and history that this city has to offer. I've brushed up on my politics and now have a greater appreciation for what goes into running our nation.

My stay with the Space Studies Board would not have been the same if it weren't for the amazing people who work here. I'd like to thank everyone for their encouraging and caring nature, you made me laugh every single day!

When I return to the University of California, Santa Cruz, I will bring back with me all that I have learned here in the past few months.

LLOYD V. BERKNER SPACE POLICY INTERNSHIPS

WE ARE CURRENTLY ACCEPTING APPLICATIONS FOR INTERNSHIPS FOR 2010.

The goal of the Lloyd V. Berkner Space Policy Internship program is to provide promising undergraduate and graduate students with the opportunity to work in the area of civil space research policy in the nation's capital, under the aegis of the SSB.

Established in 1958 to serve as the focus of the interests and responsibilities in space research for the National Academies, the Board provides an independent, authoritative forum for information and advice on all aspects of space science and applications, and it serves as the focal point within the National Academies for activities on space research. It oversees advisory studies and program assessments, facilitates international research coordination, and promotes communications on space science and science policy between the research community, the federal government, and the interested public. The SSB also serves as the U.S. National Committee for the International Council for Science (ICSU) Committee on Space Research (COSPAR).

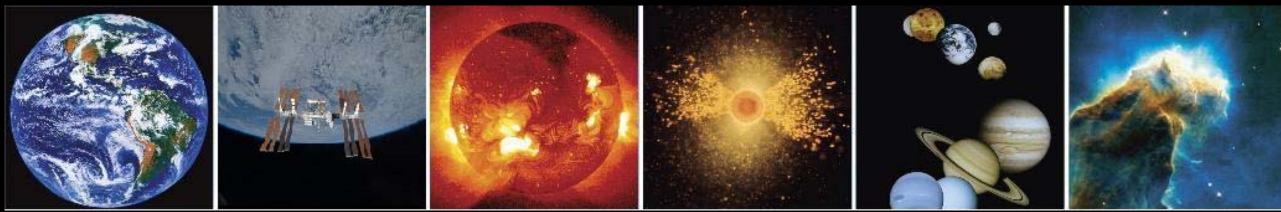
The Lloyd V. Berkner Space Policy Internships, named after the first chair of the SSB, are offered twice annually. The summer program is restricted to undergraduates, and the autumn program is open to both undergraduate and graduate students. The deadline for applications for the summer 2010 program is February 1, 2010. The deadline for applications to the autumn program is June 14, 2010. Successful candidates for the summer and autumn programs will be contacted no later than March 1 and July 2, respectively.

Individuals seeking a Lloyd V. Berkner Space Policy Internship must have the following minimum qualifications:

- Be a registered student at a U.S. university or college;
- Completed his/her junior year, majoring in physics, astronomy, chemistry, biology, or geology (other areas considered on a case-by-case basis);
- Have long-term career goals in space science research, applications, or policy;
- Possess good written and verbal communications skills and a good knowledge of his/her particular area of study;
- Be capable of responding to general guidance and working independently; and
- Be familiar with the internet, world wide web and basic research techniques (Familiarity with Microsoft Word and HTML is highly desirable, but not essential).

NOTE: SELECTION OF INTERN AND INITIATION OF PROGRAM IS DEPENDENT ON AVAILABILITY OF FUNDS.

Visit http://sites.nationalacademies.org/SSB/ssb_052239 to learn more about the internship program and to get application information.



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SSB CALENDAR

JANUARY

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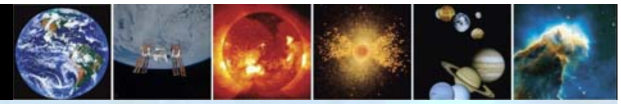
January 11-12	*Cost Growth in NASA Earth and Space Science Missions*—**Boulder, CO**
January 12-14	*Decadal Survey on Biological and Physical Sciences in Space-Integrative and Translational Research for the Human Systems Panel*—**Irvine, CA**
January 13-14	*Decadal Survey on Biological and Physical Sciences in Space-Applied Physical Sciences Panel*—**Irvine, CA**
January 13-15	*Decadal Survey on Biological and Physical Sciences in Space-Plant and Microbial Biology*—**Irvine, CA**
January 18-19	*Decadal Survey on Biological and Physical Sciences in Space-Fundamental Physical Sciences Panel*—**Washington, DC**
January 19-20	*Committee on the Assessment of NASA Laboratory Capabilities*—**Washington, DC**
January 25-27	*Astro2010-Steering Committee*—**Irvine, CA**
January 28-29	*Decadal Survey on Biological and Physical Sciences in Space-Translation to Space Exploration Systems Panel*—**Washington, DC**
February 15-17	*Decadal Survey on Biological and Physical Sciences in Space-Steering Committee*—**Irvine, CA**
February 17-19	*Committee on Origins and Evolution of Life (COEL)*—**Irvine, CA**
February 22-24	*Planetary Science Decadal Survey-Steering Committee*—**Irvine, CA**
February 28-March 2	*Astro2010-Steering Committee*—**Irvine, CA**
March 8-10	*Space Studies Board*—**Washington, DC**
March 31-April 2	*Decadal Survey on Biological and Physical Sciences in Space-Steering Committee*—**Irvine, CA**



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Remember to include the name and quantity of each report that you are requesting.

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