***The views expressed in the following columns do not necessarily reflect those of the SSB or the National Research Council.***

**SPACE STUDIES BULLETIN**
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Earth system science in America is at a turning point.

On the one hand, U.S. Earth observations are enjoying a golden age. The Earth Observing System (EOS) is providing a cornucopia of observations. With advanced communications and multi-disciplinary laboratory facilities, research ships have never been so capable. Moreover, if recent advances in sensor-net technology and cyber-infrastructure can be captured, Earth system science, together with the environmental, hydrological, and ecological sciences, is poised to make great progress.

On the other hand, the golden age is nearly over. Two of the largest government programs that have played key roles in advancing Earth system science have uncertain futures.

The EOS satellites are aging, the system will not be renewed, and replacement planning is in disarray. In retrospect, NASA's decision to not continue the system concept and instead rely on incorporating climate instruments in the payloads of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) was unfortunate. NPOESS, an operational system, did offer management commitment to long-term observations, but it did not have a strong policy commitment to climate observations. Climate was second priority; weather came first. When large cost overruns and delays overtook the NPOESS program, a natural, if unfortunate, response was to delete key climate measurements from the payload.

Choosing NPOESS for climate was a retrograde step, scientifically and managerially. Its architecture—a very large multi-instrument spacecraft—resembles the original EOS and not the flexible multi-spacecraft network that EOS became. Had NPOESS been designed like EOS, it might have been able to minimize the expensive, hard-to-resolve conflict between climate and weather. Such conflicts are inherent in engineering large complex spacecraft in any case. The first launch of NPOESS has now been delayed until 2014, so its climate data would have left gaps in continuity.

The SSB recently completed a decadal survey of Earth science and applications from space,1 with an interim report published in 2005 and the final report in 2007. The interim report documented an Earth observation program that it concluded was "at risk of collapse." As part of a strategy to reverse this trend, the final report recommended 17 missions to be flown by NASA and NOAA in the coming decade. (It notably did not address how they might be integrated into a single system capable of coordination with in situ observations.) The report further noted that there is a lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems, citing the elimination of the requirements for climate research-related measurements on NPOESS as "the most recent example of the failure to sustain critical measurements." That point was amplified in a more recent SSB report,2 which noted that short-term actions would not address the longer-term structural problems associated with providing climate-quality measurements from space systems that are designed to meet national objectives more closely associated with operational weather forecasting. The future remains uncertain, in part because NASA no longer includes Earth observations among its prime missions.

The ships in the University-National Oceanographic Laboratory System (UNOLS) are also reaching the ends of their lifetimes, and there is no clear path to replacement of the academic research fleet. UNOLS has been sustained over the years by an agreement that the U.S. Navy would fund the capital costs and National Science Foundation (NSF) the operating costs of the research fleet. This arrangement has deteriorated, and it has proven difficult for the Navy to fund the next generation of research vessels. In the meantime, higher fuel costs and operating expenses are forcing NSF to reduce the number of research cruises from its fleet.

The oceanographic research community no longer focuses exclusively on ship-borne observations as it did when UNOLS was founded in 1972, but now uses automated observing systems and space observations as well. This dispersion of focus blurs the impact of community advocacy for UNOLS. This problem will not be resolved until there is a unified plan that embraces ships, observing systems, and space observations. In other words, ocean science must plan from an Earth system science point of view.

When large central programs like EOS or UNOLS falter, a key contributing cause has to be an unclear sense of direction. The present difficulties stem in part from conflicts engendered by Earth

system science's transition from a pure research enterprise into one that supports more applications. The conflicts are manifested by disagreements within the government about the relative roles of NASA, NOAA, USGS, and NSF. In the research community, there are disagreements about "science vs. applications," "discovery vs. monitoring," "ships vs. observing systems," and "research vs. operations."

Are the U.S. science and applications agencies presently able to provide forceful leadership? They have done so in the past and they can do so in the future. This does not necessarily mean that the government is presently configured to meet the new challenges ahead. The challenge of coordinating the programs pertinent to the Earth system science agenda were understood at the beginning, when the first Bush administration founded the U.S. Global Change Research Program (USGCRP) in 1990. USGCRP is an interagency forum represented at the head of program level. USGCRP scored major early successes by harmonizing the research goals of its participating agencies and by providing a framework for EOS. As time passed, however, needs to develop multi-disciplinary technical infrastructure requiring the participation of more than one agency emerged. Here, the USGCRP was less successful because it could not enforce the budget coordination on a sustained basis that is required to build and maintain infrastructure. The second Bush administration established an even more powerful coordinating council, represented at the head of agency level, and added the Climate Change Science Program to the USGCRP to provide a stronger focus on key policy issues.3 However, this more powerful interagency council was unable to prevent the serious deterioration in the capacity to observe the Earth from space. This decline is only beginning to be reversed.

Is the government ready to provide the new decision support services made possible by its investments in Earth system science? Yes and no. By and large, NOAA, in partnership with NASA, has successfully addressed its primary mission, weather, for close to 40 years. It has done less well with its newer responsibility, climate. One reason is budgetary, which limits the technical capacity NOAA can deploy for climate-related purposes when it must continue its weather mission. But there is a more profound reason: NOAA alone is not configured to provide comprehensive Earth system services, since its mandate does not extend to the land. USGS, which does have responsibility for the land, does not deal with the oceanic and atmospheric processes that convey the impacts of climate change to the ecosystems and watersheds it is responsible for.

Recently, there has been a proposal to create an independent agency by bringing NOAA and USGS together to form an Earth System Science Agency (ESSA). ESSA would be responsible for translating the research of NASA, NSF, DOE and others into Earth system applications. In particular, ESSA would have the capacity to assess the regional impacts of climate change and to support decision-making about adaptation to climate change. And there is at least one other managerial advantage. NASA has supported NOAA's weather mission by providing space technology and building weather satellites for 40 years; it could equally well support an ESSA, with one difference: NASA would have a customer who needs an Earth observing system.

The conflicts within Earth system science will not be resolved until it is realized that the future lies in connecting research and applications. Until the conflicts are resolved, institutional progress will be stymied. The key steps toward resolution include: U.S. science and applications agencies providing forceful leadership within the United States; the United States asserting more vigorous leadership in the international Group on Earth Observations (GEO) and its Global Earth Observation System of Systems (GEOSS); and above all, the Earth system science community adopting sustainability as a long-term goal.

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[1]National Research Council, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation,* The National Academies Press, Washington, D.C., 2005; National Research Council, *Earth Science from Space: National Imperatives for the Next Decade and Beyond*, The National Academies Press, Washington, D.C., 2007.

[2]National Research Council, *Ensuring the Climate Record from the NPOESS and GOES-R Spacecraft: Elements of a Strategy to Recover Measurement Capabilities Lost in Program Restructuring*, The National Academies Press, Washington, D.C., 2008.

[3]For a recent review see National Research Council, *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results,* The National Academies Press, Washington, D.C., 2007.

**SPACE STUDIES BULLETIN**
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Historians sometimes speak of the "long 19th century." They argue that the 19th century's culture and politics took shape in 1789 with the French Revolution and ended in 1914 with the outbreak of World War I. Will future historians say that the 21st century really began in 2008 with the economic collapse? Does NASA's voyage into a new space age begin in 2009?

NASA is a child of the 20th century. Born when the nation was first grappling with the existential threat of nuclear extinction, NASA became an expression of national purpose. The United States would prevail in the Cold War, not because of military superiority (though that was important), but because of the superiority of our political institutions, our science and technology, and our democratic educational systems. Ordinary people around the world may not have seen the weather satellites, the global positioning satellites, the research satellites, or the many other fruits of the first space age, but they did see astronauts landing on the moon, and they saw in them an expression of American values and purpose. They see astronauts orbiting overhead today. Space Station Freedom has become the International Space Station, signaling a new world order and openness to working with old adversaries.

NASA has created a unique institutional culture—a blend of scientists, engineers, and the military. Scientists want to understand things never understood before, engineers want to build things never built before, and the military strives for the discipline to achieve great things in the face of danger. All three approaches to life and work are needed to achieve NASA's purpose, but they do not always fit comfortably together. All three cultures have spoken up in the public debate about who will be the next NASA administrator. Properly so; however, should mutual respect for each other's values lapse, NASA will lose its clarity of purpose. We cannot allow this to happen, for there are more questions than answers about NASA's future.

The voyage into the second space age begins this year. How should NASA start this journey? How will NASA assure its access to space for humans? Will NASA assume a leadership role in the global struggle with climate change—the 21st century's existential threat? Can an extended mission for the International Space Station express a new approach to the world? When should humans return to the Moon or go to Mars? Where else should they go? Which grand challenges of science will NASA take on first? Detection of gravitational waves or Earth-like planets? Dark energy? Predicting the solar cycle? Past oceans on Mars? Life in the Universe? Space medicine? Variable gravity technology? Will we do these things alone or with old and new international partners? Which new partners?

All these questions and more await the new president and the new NASA administrator. Only one thing is clear—NASA is vibrant only when it serves a higher national purpose. NASA exemplifies the best *of* America—our curiosity, our ingenuity, and our courage. Now NASA must do its best *for* America.

**SPACE STUDIES BULLETIN**
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As I write, our president has just completed his first trip abroad to meet with the leaders of the 20 greatest economic powers on Earth. As they struggled to find common ground in their approaches to the global economic crisis, one could see the beginnings of a new world order in the making—a world in which, President Obama has promised, America would not—could not—act as a hegemon, but would strive to lead in the role of "first among equals."

As it is in the world at large, so it will be in space. Much as some may regret the loss of our complete dominance of the space enterprise, the competitive arena brings opportunity. Nearly all of NASA's major space projects in the past 25 years have involved Europe or Japan or Russia, or in the case of the International Space station (ISS), all three. The ISS partnership has survived changing governments, budget lapses, and periods when the larger political atmosphere was antagonistic. NASA and its partners have been creative in dealing with the complexities of international collaboration and have gotten the work done.

Note that the economic crisis required the attention of the G-20, not just the G-8, which has our present major space partners. New candidates are knocking at the door of the spacefarers' club—China, India, and others. Scientific talent knows no boundaries, and many countries large and small now are working effectively on space research. We are seeing the evolution of a truly global space enterprise. In the fullness of time, financial and intellectual resources of at least a factor of ten larger than at present will be available to the global space community.

It is not too soon to start thinking about this new world order. What new kinds of scientific investigations are possible, with additional financial resources, and the efforts of many more talented people and capable institutions? Will human exploration beyond the Moon, and to Mars and beyond, only be possible at the global scale? Will the global space enterprise populate the solar system with networks of instruments, for things like gravitational wave interferometry? Will we routinely monitor every planet in the solar system? Will a global space enterprise be required to go beyond diagnosing the world's climate problem to mitigating it, as some have suggested?

It is also not too soon to start thinking about how to get started. Are the arrangements and organizations that currently support international space cooperation scalable to the global level? How should the spacefarers' club prepare for new members? How do old and potential new members get to know one another? Should the ISS partnership be open to new partners? Will a global space project be managed the way big projects are today? Will it be a large top-down international bureaucracy, or will the algorithmic methods that spread the internet around the world integrate space research and exploration?

Could NASA's promotion of a global space enterprise serve President Obama's goals? Could it help strengthen relations with China and India? Could NASA's leadership as "first among equals" exemplify the broader goals of U.S. foreign policy? NASA projects have done so in the past, and they could do so in the future.

All of these issues, and many more, were debated by the participants in a workshop entitled "Future International Space Cooperation and Competition in a Globalizing World" in Irvine, California, on November 18-20, 2008. The workshop was sponsored by the Space Studies Board and the Aeronautics Space and Engineering Board. A talented team led by Jim Zimmerman, former NASA European Representative and Chief of NASA's International Planning and Programs Office, kept a record of what was said, and you will find many interesting and creative ideas in the team's workshop report, which is coming soon to an NAS newsstand near you.

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As I write, accomplished astronaut Charlie Bolden is being confirmed by a unanimous vote of the Senate as the twelfth NASA administrator. The able Lori Garver, who headed the NASA transition team, is also being confirmed as deputy administrator. Interim administrator Chris Scolese may now return to his regular duties with the thanks of the entire U.S. space community for a difficult job extremely well done.

NASA is at a turning point in its history, and not just because it and the country have new leadership. NASA is in the midst of the crisis associated with the retirement of the space shuttle, which many predicted. With shuttle retirement comes the need to chart a new course for human spaceflight. What NASA chooses to do in the next 2 years will determine what is possible in the next 40 years.

A new philosophical course was set by President Bush's announcement of the Vision for Space Exploration in 2004. It was time to begin exploring space beyond low Earth orbit (LEO) and to aim toward an eventual human landing on Mars. This was to be done on a "go as you can pay" basis.

The first instantiation of the "Vision" is the Constellation program. A new human-rated launch vehicle, ARES-1, is to be developed and flown by 2015. A heavy-lift cargo vehicle, ARES-5, is in development in tandem with ARES-1, as are a crew capsule, Orion, and a landing vehicle, Altair. The next beyond-LEO target is the Moon, with an initial U.S. landing in 2018, now pushed back to 2020.

In order to pay for Constellation, other NASA programs have had to give. Constellation's budget assumes that the shuttle program will come to a hard stop in 2010 and that the International Space Station (ISS) will be sent into the atmosphere in 2016, after only 5 years of full operation. The 2015 and 2018/20 deadlines also have meant that other development costs have been pushed back before 2010, with predictable consequences for NASA science and aeronautics.

Five years in, it now appears that we cannot go to the Moon because we can not pay. The combination of budget pressures, technical difficulties, and policy considerations have made it unlikely that the Vision's schedule can be met, even with strong assumptions made about the shuttle and the space station. Moreover, shuttle launches may extend into 2011 for safety reasons, and it is not at all clear that people will be comfortable with an early retirement of the station. All this pushes any reasonable prospect of a human lunar landing into the 2020s or beyond. Perhaps the Chinese will get there first.

What to do about all this is the question before the Augustine Commission, which is to report to the president's science advisor and the NASA administrator by the end of August. The Commission will evaluate the current program as well as alternate approaches. All options should assume that the shuttle is eventually retired, and most should conform to the go as you can pay principle. A huge decision for space remains even with these constraints. What are our mid-term goals? Long-duration ISS operations? The Moon? Direct to Mars? An asteroid? Which launch vehicle should we use for humans? Cargo? Do we need two? Should we extend ISS beyond 2016? Can ISS support beyond-LEO exploration? How should NASA and the aerospace industry deploy their human resources? What might we expect from increased international cooperation? How will the nascent commercial involvement in the exploration program evolve?

The National Academies can be proud of the contributions it has already made to the Augustine Commission. The National Research Council (NRC) report on the civil space program, *America's Future in Space: Aligning the Civil Space Program with National Needs*, chaired by General Lester Lyles, and our SSB workshop on international cooperation, *Approaches to Future Space Cooperation and Competition in a Globalizing World: Summary of a Workshop*, were completed and distributed during the Commission's deliberations. They have had a measurable effect.

There are vital issues beyond exploration. The Commission is planning to hear from the chairs of our decadal surveys, and not just about what science might be done in the exploration program. It is even more important for the Commission to keep in mind what is at stake for the entire space science enterprise as it considers options for human spaceflight.

A year from now, NASA will be on a different course. The charts on which this course is plotted are being drawn now.

**SPACE STUDIES BULLETIN**
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I cannot believe I am writing this. I am about to argue that the scientific community ought to help rehabilitate the mission of the International Space Station (ISS).

I have always been a critic of the International Space Station. When I was the chair of the NASA Advisory Council (NAC), we excoriated NASA's undisciplined management of the ISS project. Worse yet, NASA was unable to account for its costs and delays satisfactorily. NASA took our recommendation to limit its focus to completing the station and fulfilling the commitments to its international partners. In the event that this came at the expense of NASA's own plans to use the station.

The NAC also took NASA to task because NASA was not paying much attention to what to do with the station once it was built. The American public had no idea what the station was for. The situation got worse when NASA's Life and Microgravity Sciences Program was cannibalized in favor of ISS construction, and a long-suffering science community, which had been patiently waiting to fly its experiments on the station, was dispersed. The extraordinarily strained relations between the science and human spaceflight communities were a contributing factor leading to the departure of three scientific members, including me, from the NAC.

By then the *Columbia* tragedy had occurred, and in the aftermath President Bush announced the Vision for Space Exploration. NASA was to return the space shuttle to flight, complete the space station, fulfill its obligations to its international partners, and retire the shuttle in 2010. NASA was also to create a new architecture for human spaceflight that focuses on exploration beyond low Earth orbit—the Constellation program. Shuttle and station operations seemed repetitive and boring, but a landing on the Moon might reawaken the old passion for space exploration.

To its credit, NASA is completing construction of the station. Even when its own plans to use it were vague, it kept its commitments to its international partners, so they could carry out their plans. On the other hand, the absence of a forceful user community in the U.S. probably made it easier to plan to de-orbit the station in 2015, after only 5 years of full utilization of a project that was 25 years in the making. The station funding was needed after 2015 to complete the Constellation Program.

In May of this year, the President and NASA convened the "Augustine Commission" to develop options for the future of the human spaceflight program. As this newsletter is published, the Augustine Commission's final report has been released (available at http://www.nasa.gov/offices/hsf/home/index.html), and its general conclusions are known through its public presentations and Norman Augustine's testimony before Congress.

Had NASA received additional funding as promised, it might have been possible to complete the Constellation program. That funding did not materialize: Constellation cannot be executed within the present NASA budget. Another $3B/year would be required for exploration beyond low Earth orbit in the next decade. This, the president will have to decide.

In the meantime, the International Space Station is one of the principal beneficiaries of the Augustine report. With the exception of the Constellation-based scenarios, all others discussed by the Augustine Commission recommend an extension of the station through at least 2020.

Why did the commission do this? Space exploration connects with the global public, and NASA's leadership in space promotes American leadership in the world. The ISS has proven that many nations can work together toward a distant and difficult goal. It expresses a U.S. leadership style adapted to today's multi-polar world and tomorrow's global challenges.

Aside from the space station itself, the most valuable asset produced by the ISS project has been the proven and tested working-level relationships among the partners. This partnership has weathered budget problems, changes in governments, lapses in commitments, and the *Columbia* tragedy. A good partnership already exists, and it could evolve the global partnerships that will be needed for human exploration beyond low Earth orbit, and, I may add, large science projects like Mars sample return.

I also believe extension of ISS operations to 2020 and beyond could be a game-changer. The few projects now on the drawing board might be flown by 2015, but new users would have no hope and would not even try. Because ISS did not have much of a future, people were not thinking of what they could do with it. At the same time, NASA, which never paid much attention to using the station, will have to change its ways to attract new science and technology users. It will need to fund utilization generously. *And,* it will need to take utilization management out of the hands of the people who built the station.

The Space Studies Board's Decadal Survey on Biological and Physical Sciences in Space is the right place to identify the new scientific opportunities made possible by an open-ended ISS program. It can help define the new organization needed to manage the interface between the flight operations and user communities. Perhaps for the first time there will be people who really have to listen.

Now, I don't expect that the ISS will change science as we know it. People don't entertain that illusion any more, anywhere. But I do think it would be a mistake for the science community not to design a program that returns value to the American and global publics.

**SPACE STUDIES BULLETIN**
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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.

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?

**SPACE STUDIES BULLETIN**
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The president proposes and the Congress disposes. That's the American way. President Obama's 2011 budget is before the Congress as I write. In many ways it is a good one for NASA. It provides an overall increase of a billion dollars per year. It improves funding for aeronautics and provides for a long-advocated advanced technology development program. No science program is taking a funding cut, and some are increased, a welcome change from the trends of recent years.

The big beneficiary is Earth science, whose funding will be restored to what it had been at the end of the Clinton administration. Just as important is the president's policy guidance. NASA can develop the missions recommended by the SSB's decadal survey, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*, for basic research in Earth system science, and now also has authority and funding to undertake certain long-term measurements important to understanding climate, thereby settling a long debate about which agency should make them.

The president made important decisions about other agencies important to NASA Earth science, as well. NSF geosciences will receive a substantial increase. NOAA can initiate its long-planned Climate Service. The administration resolved the NPOESS dilemma by canceling the program, long considered a disaster. The Air Force will have the authority to develop its own weather satellite for a morning Sun-synchronous orbit, and NOAA can develop an afternoon satellite in partnership with NASA, an arrangement violated by NPOESS that served the country well for over 40 years.

NASA's astrophysics budget receives virtually no increase in the 2011, budget and none is presently forecast for subsequent years. This appears to leave little leeway to fund the soon-to-be forthcoming recommendations of the NRC's Astro2010 Decadal Survey. Rather than think that the administration has an animus towards astrophysics, I prefer to believe that this is typical OMB caution: the budgeters do not commit to programs that are yet to be defined. However, astrophysics will clearly be an issue for the 2012 budget and beyond.

There is a very large problem with Congress' reception of the budget for human spaceflight. The president, clearly influenced by the report of the Augustine Commission, cancelled the Bush administration's Constellation Program, and chose to depend on foreign partners and a newly developing U.S. commercial launch industry for both re-supply and human missions to the International Space Station.

One could have predicted that this would be politically controversial, but I for one did not anticipate the firestorm of opposition from members of Congress whose districts are affected by the losses of the space shuttle and, now, Constellation. President Obama, taking it seriously, has just hosted a town hall meeting in Florida where he proposed to continue developing the Orion capsule, a part of Constellation, for use as an escape module for the International Space Station, as well as other measures designed to address some of the concerns expressed by the Congress. Let us hope this dispute can be settled soon, lest the other good things in the NASA budget languish.

Sometimes it is wise not to fret about every complexity of the present scene. Things settle out when we take the long view. If you are interested in the long view, come to the Space Studies Board's next workshop, to be held at the National Academies' Arnold and Mabel Beckman Center in Irvine, California, November 8-10.

Originally, we thought we would look at how effectively NASA is using both old and new media in getting its story across to the general public. As time passed, we came to realize that NASA's most convincing story is how its accomplishments speak to the grand philosophical questions people care about: Are we alone? How did the universe begin, and how it is evolving? How did the solar system form and how is it evolving? Will the earth remain a hospitable home for humanity? What does the future hold for human exploration of space? Do nations aspiring to become great need space programs? We will look back 50 years and look ahead 50 years. We will invite prominent space scientists to take a broad look at these questions. We will invite panels of media professionals to tell us how they would express the same questions and answers. We will allow plenty of time for dialogue with the audience. Because of its public nature, we anticipate a larger audience than usual, we have reserved the Beckman Center's largest auditorium, so there should be plenty of room. You are all invited. Do come. If you are interested, please contact Ian Pryke (Ipryke@nas.edu).

On behalf of the members of the Space Studies Board, I wish to express our appreciation for the calm and insightful leadership Dick Rowberg brought to the task of interim staff director. Dick took on an

extra workload and did it well. It is now our pleasure to announce Michael Moloney as our new staff director. Michael comes to the Board after an arduous assignment as study director for the Astro2010 Decadal Survey. Welcome aboard, Michael.

**SPACE STUDIES BULLETIN**
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I wear two hats these days. I am your Space Studies Board (SSB) Chair, and I also chair the California Council on Science and Technology (CCST). CCST, which is modeled on the National Research Council, provides advice on science and technology (S&T) to the government of the state of California. For the SSB, I get to preside over discussions about what advice to give NASA about its future programs. For CCST, I preside over discussions about what science and technology can do for the people and economy of the state, and what the state could do to encourage its S&T community.

On May 17, 2010, the California legislature, in a bill sponsored by 13 members from both the Assembly and the Senate and from both sides of the aisle, asked CCST to undertake a comprehensive study of "California's science and technology (S&T) innovation infrastructure and 'ecosystem,' analyzing and reporting current global innovation systems, and recommending to the Legislature actions that should be taken to sustain the state's role as a global leader in science and technology."

This is a pretty tall order, but the first step is always the hardest. We had no trouble taking it. On May 25, CCST and the California Space Authority co-sponsored "Space Day" in Sacramento, which was kicked off by a highly popular screening of "Hubble 3D" in the IMAX Sacramento Theater across from the Capitol, and continued the next day with CCST discussions of California's space economy. In a state that is home to Silicon Valley and two of the world's great biotechnology centers, it is significant that CCST started its study of innovation with space.

By any measure, California is the largest aerospace state in the country. Three of NASA's centers are located in California and 20 percent of NASA's budget is spent in California. The Defense Space Command is located in California, as are numerous aerospace firms, large and small. The California Space Authority estimates that aerospace companies and suppliers located in California employ at least a half a million people.

Let's look at what NASA centers do in and for California. The Jet Propulsion Laboratory, with about 5,000 employees, is the world's leading center for interplanetary space missions and, along with Goddard Space Flight Center, a leader of NASA's Earth science programs. The Ames Research Center, with about 1,200 civil servants, is NASA's portal in Silicon Valley. Its job and its destiny is to capture ideas created in the valley, turn them to NASA's benefit, and in turn stimulate innovation in the companies nearby. Ames manages NASA's Astrobiology Institute (no accident), which is designing innovative robotic precursor missions for deep space exploration and is innovating small satellite subsystem technologies. Dryden Flight Research Center (about 550 civil servants), NASA's experimental flight support facility, is becoming a center of innovation too, as the region surrounding Edwards Air Force base, where Dryden is located, has become home to a cluster of entrepreneurial aerospace firms building next generation space vehicles.

Why should non-Californians pay any attention to all this? Perhaps it is because we have learned that California and NASA need each other. NASA's intellectual network extends beyond its centers directly into the heart of its surrounding science and technology communities. NASA both draws on and stimulates the communities in which it lives. NASA's challenging goals attract a special kind of person, and its unusual programs prompt the development of new knowledge and inventions. No one of the NASA centers could do its work without the talented people who specialize in communications, sensors, robotics, materials, nanotechnology, biotechnology, propulsion, human factors, and many other things.

Of course, CCST is not the first to recognize that having a NASA program is good for regional economic development. But too many people view NASA's presence solely in terms of the number of jobs at a NASA center or the number employed on NASA contracts and grants.

NASA is not, repeat not, a jobs program. Look at the numbers. NASA's direct employment is not more than 10,000, yet the California Space Authority estimates there are half a million people working in aerospace in California. Many people cite the technological fallouts from NASA work, but even that, I think, undersells NASA. I view NASA as a goals and talent program that animates and energizes the regional knowledge networks around it.

So what should the states and countries angling to supplant California's leadership in space do? Invest in education and build communities of talent. Build them, and space leadership will come.

**SPACE STUDIES BULLETIN**
**VOLUME 21, ISSUE 3 July-September 2010**

***This article was written by A. Thomas Young as his term as the SSB Vice-Chair concluded.***

My tenure as a member of the Space Studies Board (SSB) is about to conclude. When I was invited to join the SSB 6 years ago I was honored; I was even more honored when asked to be vice chair. This is an opportunity for me to offer some observations on the Board and the state of the civil space program.

The SSB has two very important attributes to offer in the conduct of space studies—knowledge and integrity. I have been greatly impressed with the extraordinary individuals who are members and even more impressed with the synergy that is represented by the Board as a whole. This remains true as members rotate on and off the Board. However, knowledge alone is not adequate to meet the needs of space studies sponsors. Integrity is another critical ingredient to ensure that SSB reports serve only one master which is in the best interest of the space program. The SSB is truly an "honest broker." I would be remiss if I did not highlight the exceptional SSB staff that makes the total operation function and makes all of us look good.

Currently, the most significant contributions of the Board are the decadal surveys which define strategies for each element of the U.S. space science program. I have had the privilege to be a member of three decadal surveys. The most frustrating aspect of the surveys is that the list of worthy activities not included in the resulting recommendations greatly exceeds what affordability allows to be included. This is testimony to the quality of the resulting recommended program. My observation is that the members of the decadal surveys treat their responsibilities with the utmost seriousness, and they are dedicated to excellence and maintain uncompromising integrity. The surveys' outreach, inputs from the community, study, analysis, and debate are comprehensive and most remarkable. The resulting product is clearly the best of the best. We must ensure that the integrity of the decadal surveys is not compromised and continues to represent the "gold standard" in defining the future of space science.

While I am most impressed with the quality of SSB membership and reports, I am disappointed that the full potential of the SSB is not being realized. The policies that govern the operation of the Board can be constraining. The enormous expertise represented by the Board is not being applied to crucial issues, and the loser is the U.S. space program. Hopefully over time a better balance between "rules" and contributions will be achieved.

The state of the U.S. civil space program is mixed. The accomplishments of the science program are incredible and I strongly believe the opportunities available in the next few decades are greater than the extraordinary achievements of the past few decades. For example, the Mars Science Laboratory (MSL) and the James Webb Space Telescope (JWST) have the potential to enormously increase our knowledge of Mars, our solar system, and the universe. However, MSL and JWST cost and schedule issues are present of major credibility challenges. We must do a better job of program management and, in particular, establishing the most probable budgets.

Human spaceflight since Apollo has been dominated by the space shuttle and the International Space Station. These are truly remarkable engineering and operations achievements. However, no human space exploration has occurred since Apollo 17, and we have been unable to establish a program that has a sufficient commitment to see it through to implementation. This has resulted in a highly inefficient use of human exploration resources. Currently there is debate as to what the human exploration program should be. Mars appears to be the consensus ultimate objective. However, the intermediate program is ambiguous. We badly need a high-quality, exciting, and executable program. For too long we have had more program than the budget would support. Either we must have more budget or less program. This is true in the human and robotic programs. Continuing to pursue a program that is not executable will assure another "train wreck." We will accomplish more with a smaller program that is executable within budget limitations than by pursuing a larger, more attractive program that is not executable within the available budget.

We have had five decades of remarkable accomplishments. The next five decades are populated with challenging and exciting opportunities. To realize this potential, the total space community must be integrated and focused upon the success of the program to provide knowledge, technology, pride, prestige, and inspiration.

**SPACE STUDIES BULLETIN**
**VOLUME 21, ISSUE 4 October-December 2010**

They said it couldn't be done. How many times have you heard it said that the Academy can't even choose a committee, much less write a report, in time to influence fast-breaking decisions? (On second thought, don't answer.)

But it has been done. It all started when the NRC's decadal survey of astronomy and astrophysics, *New Worlds, New Horizons in Astronomy and Astrophysics (NWNH)* was released last August. A joint product of the Board on Physics and Astronomy and the Space Studies Board, NWNH was the first decadal survey to take engineering, management, and independent analysis of technical readiness and cost issues into account in the formulation of its research strategy. The increased ability to estimate mission realism gave the survey the confidence to synthesize mission concepts from the many ideas that they heard from the research community. This played a role in developing NWNH's recommendation for the Wide-Field Infrared Survey Telescope (WFIRST) mission. The survey saw that such a space telescope could achieve not one but three goals of the astronomy and physics communities: to make much more precise measurements to determine the role dark energy plays in the dynamics of the universe by surveying hundreds of millions of galaxies in the infrared, to refine our understanding of galaxies and clusters using WFIRST's vast quantity of data, and to make progress on the detection of extrasolar Earth-like planets using microlensing.

WFIRST was not the whole story, of course, and the survey gave equal weight to a program of principal-investigator-class missions and broad disciplinary support. However, since WFIRST was NWNH's highest-priority large space-based mission, it was bound to attract attention. To add to the attention-getting, the survey recommended that the United States play a strong leadership role in implementing WFIRST, going it alone if necessary.

Meanwhile, major delays and very large cost and schedule overruns in the James Webb Space Telescope (JWST) project are taking place. These were and are going to affect NASA's whole astrophysics program. Moreover, the budgetary guidance given to the decadal survey was no longer pertinent. NASA, which did not want to see the United States shut out of dark energy research, had started to explore with the European Space Agency (ESA) the possibility of a 20% participation in ESA's *Euclid* mission, which will compete this summer for a 2018 launch opportunity.

The NWNH's WFIRST recommendation and the news that NASA was pursuing *Euclid* hit the streets at about the same time. At this point, the White House got involved, and the Office of Science and Technology Policy requested an Academy evaluation of the WFIRST-*Euclid* choice. Given ESA's short decision time and the approaching president's budget request for FY2012, any NRC study had to be done quickly, so that NASA could make a *Euclid* recommendation (or not) in its next budget request.

This is when the avalanche of work started. It would take too much space to recount here how a hard-working panel considered in depth the scientific merits of WFIRST and *Euclid*, and how it also interpreted what the survey committee had really meant. You can read the panel's report for yourself (www.nap.edu/catalog.php?record_id=13045), but in summary the *Report of the Panel on Implementing the Recommendations from New Worlds, New Horizons Decadal Survey* had three broad conclusions. The best outcome would be if JWST's budget overruns were magically solved outside the astrophysics program. Second best, or potentially first best, would be if NASA and ESA were to design a joint mission reflecting the WFIRST capabilities outlined in NWNH. Finally, minority participation in *Euclid* was not a recommendation of the decadal survey.

NASA and ESA have been put in a delicate situation. Very careful international negotiations will be needed. However, if the present goodwill between NASA and ESA continues, we can hope for a reasonable outcome. In the end, it is all about the best science.

A hardy band of heroes—committee members and NRC staff—working days, nights, and weekends, completed this report in 8 weeks**.** All involved were heroes, but I would like to single out my panel co-chair Adam Burrows and NRC staff David Lang, Caryn Knutsen, Michael Moloney, and Don Shapero for special recognition. We also owe a great deal of gratitude to the speakers who came to our panel's workshop at very short notice and to the NRC reviewers who turned around this report's review in record time.

Would we do it again? Not too soon, please. Would we do it again if we had to? You bet. Only next time, our goal is that the SSB will be better prepared. In this regard we are exploring how to improve the NRC stewardship of our decadal surveys after they have been released. Our recent adventure

emphasizes how important that function is.

On another note, there is important news about human spaceflight. The president's human spaceflight 2011 budget submission provoked the most divisive congressional debate about NASA that I have ever seen. Ultimately, the Senate and House passed a NASA Authorization Act, which was quickly signed into law by the president. This legislation contains a special request to NASA to "contract with the National Academies for a review of the goals, core capabilities, and direction of human space flight, using the goals set forth in the National Aeronautics and Space Act of 1958, the National Aeronautics and Space Administration Authorization Act of 2005, and the National Aeronautics and Space Administration Authorization Act of 2008, the goals set forth in this Act, and goals set forth in any existing statement of space policy issued by the President." The legislation envisions that elements of the review shall include:

> (1) A broad spectrum of participation with representatives of a range of disciplines, backgrounds, and generations, including civil, commercial, international, scientific, and national security interests;
>
> (2) Input from NASA's international partner discussions and NASA's Human Exploration Framework Team;
>
> (3) An examination of the relationship of national goals to foundational capabilities, robotic activities, technologies, and missions authorized by the Act;
>
> (4) A review and prioritization of scientific, engineering, economic, and social science questions to be addressed by human space exploration to improve the overall human condition; and
>
> (5) Findings and recommendations for fiscal years through 2023.

Many people have remarked that human exploration lacks the kinds of long-range goals that stabilize NASA's science programs; the NRC will now have a chance to address this issue in depth. Together with the Aeronautics and Space Engineering Board, we have started to plan how best to carry out this mandate. At this early stage, it is difficult to say what the scope will be other than that it will be challenging project of a scope certainly no less than a science decadal survey.

Also of interest, you may have missed one of the most stimulating workshops I have ever attended: *Sharing the Adventure with the Public: The Value and Excitement of "Grand Questions" of Space Science and Exploration.* Held in Irvine, November 8-10, this workshop featured some of the international space science world's most thoughtful communicators along with leaders of the media—traditional and modern. Together we reviewed the achievements of the past 50 years and shared our visions for the next 50 years.

When we first started planning this workshop, our question was banal: Is NASA making use of the modern tools of communication? But as our thinking evolved, we realized that NASA communicates best by what it does and not what it says. The workshop became an extended discussion of the significance of the space enterprise, not only to science, but also to global civilization.

I want to thank SSB members and the former SSB chairs and members who spent valuable time over 2 years helping to set the magisterial tone of the workshop. All the speakers evidently devoted serious thought to their presentations. But the biggest kudos go to Ian Pryke, who combined his knowledge and international connections with persistence and hard work to bring it all together. All in all, these people created one of the most memorable events I have been privileged to be part of.

You can find more information about the workshop, including videos of the entire two and half days at http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_057195. A report recounting the workshop discussions will be released soon.

**SPACE STUDIES BULLETIN**
**VOLUME 22, ISSUE 1 January-March 2011**

American science seems to choose Washington in April for major meetings. The National Research Council's Aeronautics and Space Engineering Board (ASEB) met for the 142nd time on April 5 and 6, and the Space Studies Board (SSB) met for its 162nd time on April 6-7. On April 6, the two boards met together for only the third time. Judging from the full attendance and by the turnout of NASA leaders (including the NASA Administrator Charlie Bolden), having a 1-day joint meeting to understand NASA's budget is a good idea. We should have had joint meetings years ago. I will leave it to historians to explain why we didn't.

You could not tell the difference between the two boards' worried reactions to the presentations on the projections of the 2011 and future federal budgets for the agencies that support the space sciences. This is not surprising, because problems at those agencies, including and particularly NASA, transcend our disciplines. We are both worried about programs that we have long been following, and perhaps even about the viability of NASA as we know it.

The only certain thing about NASA's future is that its future is more uncertain than it has ever been, notwithstanding the tremendous promise of the space sciences that is so clearly described by the SSB's set of decadal surveys. In the short term, no one can guess how the budget situation will evolve; in the long term, both the Administration and Congress agree that the deficit must be reduced, although they disagree on how to do it. The specific impact on NASA remains to be seen.

The president has proposed to Congress a "steady as you go" 2012 NASA budget, the level "notionally" held constant at 18.7 billion for the next 5 years. Would that it could be so! The new watchword is, as far as budgets are concerned, "Flat is the new up."

NASA is sailing on a stormy financial ocean with no sign the storms will let up soon. Certainly, there has been nothing calm about the atmosphere surrounding the 2011 budget, which was passed 6 months after the start of the fiscal year. The continuing resolution forced NASA to make expensive programmatic adjustments before its passage and, worse, delayed scientific progress.

There are unsettling omens. In 2012, NASA will lack its own capability to launch astronauts to low Earth orbit for the first time since the 1960s. Something new is also happening to the sciences covered by the SSB's decadal surveys. For the first time, the surveys are making recommendations within specific budget scenarios as well as taking cost and technical readiness into account. The recent planetary and astronomy and astrophysics surveys have recommended far fewer flagship missions than previous surveys have. What is unprecedented is not that, however; we cannot be certain that NASA will be able to do even our few high priority large-scale missions.

There is, for example, a chance the one and only large-scale mission recommended by *New Worlds, New Horizons*, for the Wide Field Infrared Telescope (WFIRST), may not be doable within the decade, and possibly not at all. NASA has made heroic efforts to complete the first priority recommendation of the last astronomy and astrophysics survey, the James Webb Space Telescope, despite enormous overruns in cost and schedule. Completing the last survey's flagship mission is directly threatening its smaller successor. Indeed, it is becoming clear that cost inflation in most if not all large projects is higher than we thought and getting higher. Launch vehicles have recently jumped in price. The current inflation in project costs compounds the other difficulties presented by a NASA budget that is at best level and likely declining.

All in all, NASA seemed to be facing a qualitatively new situation. Then, all at once, there was a ray of optimism amidst these gloomy reflections. We reminded ourselves of the many fascinating programs we are already working on. Many of these are lasting much longer than we thought they would and are supporting research objectives that were not thought of in the original proposals and surveys. Indeed, we said, the basic premise of *New Worlds, New Horizons* is that never before have so many been able to learn so much so effectively, that astronomy and astrophysics are on the brink of a new era of achievement. Notwithstanding the challenges with implementing WFIRST, NASA has adopted many of the report's other recommendations most notably an increased explorer program and augmentations of support for the smaller scale efforts, such as the programs in theory, suborbital science, and laboratory astrophysics. The SSB's recently released decadal survey of planetary science, *Visions and Voyages for Planetary Science in the Decade 2013-2022*, describes an exciting path forward in our studies of our solar system. Even in an area that has been severely cut back, our first ever decadal survey of life and physical sciences in space, *Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era*,

proposes constructive ways to reconstitute a high quality science program in light of the recent commitment to continue the International Space Station.

We began to see a path to the future. NASA's capabilities and those in the U.S. science and engineering communities remain unrivalled. The United States still leads in both space science and exploration. If we scientists and engineers continue to execute the programs we have as well as we have, others around the world will still be drawn to collaborating with us because of our technical excellence and not our financial power. We can lead the world by example.

I hope you might indulge my personal reminiscences, because as I write *Atlantis* is being prepared for space shuttle's final flight. I was a very young, very green new member of the Space Studies Board when I first saw a space shuttle—the *Enterprise*—about 2 weeks before its public rollout in Palmdale. *Enterprise*—an engineering model that would never fly—had been named for the spaceship in the now legendary TV series *Star Trek*. In retrospect, that tells a lot. Although my more wizened colleagues probably entertained doubts, I accepted without question what was said about the space shuttle—that it would make a flight a week, that human spaceflight would become routine, that its enormous cargo capability destined it to do great things. I was a little unclear about which great things, but there were going to be lots.

The space shuttle next got my attention when my scientific colleagues received a letter from NASA informing them that henceforth all scientific missions had to use the space shuttle. They dutifully sent a flood of conceptual proposals to NASA. Some of my space physics colleagues won grants. Those grants were career breakers. Even though NASA faithfully continued funding their projects for years, the promised flight rate never materialized, and my friends wrote quarterly reports on experiments that would never fly.

I recall watching the *Challenger* accident on television with colleagues at TRW Systems and sharing their grief at the loss of magnificent human beings. I first began to perceive that the space shuttle was about people. Richard Feynman was very ill at the time and staying at the UCLA hospital. We in the physics department hosted his colleagues from around the world who came to visit him. He also played hooky, spending his last energies on the Challenger Accident Investigation Board. Who can forget Feynman's explanation of what went wrong with the O-rings?

One of the great things the space shuttle was going to do was fly the Great Observatories and transform observational astronomy. This it did, but by the time the Hubble Space Telescope was launched, I too had become wizened. I recall a discussion with my SSB predecessor, Len Fisk, in his NASA office. The faulty Hubble optics were to be repaired by astronauts. I had my doubts, but I am glad I was proven wrong. Each subsequent repair mission created virtually a new Hubble telescope in space. Hubble (and the other great observatories) is one of the two greatest achievements of the space shuttle.

By the mid-1990s, I too was at NASA headquarters as Associate Administrator for Mission to Planet Earth. Although our office had abandoned the space shuttle as the launch vehicle for the Earth Observing System because of its cost, we still had developed impressive missions that made use of the space shuttle's weight-lifting capacity; of these, my favorites were the Shuttle Imaging Radar Mission (SIR-C) and its follow-on, the Shuttle Radar Topography Mission.

In my turn at the helm of NASA Earth science, I came to appreciate Johnson Space Flight Center's magnificent archive of photos of Earth taken from space by astronauts, who told me that flying in space made them all Earth scientists. They could see its fragile beauty. I also had the unique experience of being the senior executive at a space shuttle launch and simultaneously a member of an astronaut family group. By that time, I thought myself grizzled as well as wizened, but the launch brought tears to my eyes. I saw the decision, I knew the risks, I knew the people.

After returning to California, I joined the NASA Advisory Council (NAC), eventually to be its chair. By then, the NAC was warning that the low space shuttle launch rate and the high costs of each launch would make human spaceflight unsustainable. We commissioned a number of technology studies seeking an alternative to the space shuttle, but in the end we had to admit that the only feasible space shuttle replacement was a space shuttle upgrade, and we endorsed a proposal to replace the fuel tanks and make other key modifications. This would kick the can down the road for another 10 years. Then came an early morning call from my astronaut relative. He and I relived once again the awful human drama of another space shuttle accident—*Columbia*. Once again, it came back to me: human spaceflight is all about people.

The safety measures put in after *Columbia* to protect an aging space shuttle only worsened its flight rate and cost problems. But, the space shuttle had one remaining very important job—finishing the International Space Station (ISS). NASA had to keep its commitmentsto its 14 international partners, and to its very great credit, it did. To me, the most important thing about the space station is that human beings—an international team of human beings—built it. The ISS partnership persevered despite major changes in management, policy, and budget and the *Columbia* accident. The ISS has to be the most complex international engineering project ever.

I had one final sad duty to perform for the space shuttle as a member of the Augustine Commission in 2009. We had to recommend to the president that the space shuttle be retired. I was happier to recommend extending the ISS to 2020 to see if the vision once held for the space shuttle could be achieved. Maybe we will finally learn whether routine access to experimental facilities in space can produce science and technology of great value to humans on Earth.

Looking back over the years, I think I should have thought through the goals of the space shuttle at the beginning. Would I have seen the essential contradictions? That great things are never routine? That you can build a system that can do a few great things or a system that does a lot of little things but it is hard to do both? That you are disingenuous when you claim you will routinely do great things?

I think we learned that it gets very expensive when you use a system built for great things to do little things, which maybe is why the life and microgravity sciences never prospered on the space shuttle. The space shuttle was built to do great things and it did them—Hubble and the ISS. And it taught us far more than we ever knew before about how human beings can live and function in space.

NASA plans to separate the routine and the great next time around. We will access the ISS with small, commercially developed space vehicles, and we will build a new heavy lift vehicle to do the great things. We haven't said yet what those great things are. When the space shuttle was rolled out, people never said what the great things would be either. Unless we think through the goals of human space exploration in the 21st century, we will repeat the space shuttle experience. The Senate has asked the National Academies to think about the goals, and we intend to give it a try.

**SPACE STUDIES BULLETIN**
**VOLUME 22, ISSUE 3 July-September 2011**

*The Space Studies Board hasn't even completed the last decadal survey of the present round, and you're already worrying about how to do the next round? Haven't we enough problems just getting through the present decade? Why, we haven't even achieved top priorities from ten years ago!*

The Space Studies Board will devote an entire workshop in November 2012 to the lessons learned from the present round of decadal surveys while our memories are still fresh. I can already predict some of the issues people will want to discuss.

The recent astronomy and astrophysics decadal survey, *New Worlds New Horizons in Astronomy and Astrophysics*, pioneered the use of an independent cost assessment and technical evaluation (CATE) as an additional criterion for evaluation of scientific missions. Subsequently, the decadal survey for planetary science, *Visions and Voyages for Planetary Science in the Decade 2013-2022*, adapted the CATE process to its needs, and the ongoing survey of solar and space physics has done likewise. By November, it will be time to review how well the CATE process worked in these different contexts.

Did CATE promote greater credibility with Congress? With NASA? Did it take up too much time? Are there more efficient ways to generate and manage CATE information? How did using CATE support the decadal survey committee's main responsibility to identify the best science? Did we overlook emerging opportunities whose cost cannot yet be estimated? In the effort to produce financially credible program architectures, fewer missions could be given high priority—Were the budgetary scenarios used to down-select mission recommendations realistic? Haven't budget predictions already proven unrealistic? How can the surveys' decision rules deal with such major alterations in budget outlook? How should the SSB and its committees steward the decadal surveys in the off-years?

A related issue: Is it time to reconsider how we treat flagship missions? Their cost, schedule, and technical risks are high, by definition, and overruns and delays can compromise entire disciplinary programs. Should we advocate that flagship missions have significantly larger contingency budgets? NASA has had to make the James Webb Space Telescope an agency-wide priority—Does this mean that in the future not every discipline can expect a flagship mission in its decade, that all flagships should be managed at the agency level? If so, how should SSB choose priorities among the flagships recommended by its decadal surveys?

International collaboration is becoming a necessity in more and more areas. In many cases, we seek international collaborators when we find we cannot afford a mission we would love to have. We may not have planned the missions with the special capabilities of potential partners in mind—Would we get a scientifically stronger result if we plan certain missions and programs at the international level from the beginning? If so, should decadal surveys identify international mission opportunities separately? Should decadal surveys review the plans of other nations and inquire about collaboration opportunities? Should survey committees include international members as a matter of policy?

One final thought: Dwight Eisenhower once said, "plans are worthless, but planning is everything." By that I suppose he meant that even in the fog of battle, everyone still knows what he should be trying to do. It is that way with the decadal surveys, too? Certainly, our workshop in the fall of 2012 will be an interesting dialogue on these topical and important questions.

**SPACE STUDIES BULLETIN**
**VOLUME 22, ISSUE 4 October-December 2011**

***This month's column is authored by SSB Vice Chair John Klineberg***

The SSB spent some time this past year reviewing the more important issues associated with access to space for space science missions. Ann Karagozian of UCLA, study chair of the Air Force Scientific Advisory Board (AF SAB) 2010 report entitled *The Future of Launch Vehicles Systems for the USAF* presented a review of the study's findings and recommendations to the SSB executive committee at their meeting in La Jolla, CA, in August. She repeated the presentation for the Aeronautics and Space Engineering Board via WebEx at their 2011 Fall meeting in October, which I attended as the SSB's liaison. The publicly released abstract from the AF SAB Future Launch Vehicle study is available at the SAB website (https://www.sab.hq.af.mil/TORs/2010/Abstract_FLV.pdf). This study focused on military launch systems, but there is clear relevance to NASA launch vehicle issues. In addition, the SSB convened a "Focus Session on Access to Space for Space Science Missions" at their 2011 Fall meeting in November. The session included a presentation by Michael R. Luther, deputy associate administrator for programs in NASA's Science Mission Directorate. At these meetings, a number of core issues were discussed that are outlined below and will be the subject of future attention by the SSB.

U.S. military and civil payloads are required to launch on domestic vehicles, and most government-sponsored satellite launches take place on Evolved Expendable Launch Vehicles (EELVs). Since 2006, launch services for the EELVs have been provided by the United Launch Alliance (ULA), a 50-50 partnership between Lockheed-Martin and Boeing. The EELV inventory currently consists of the Atlas V vehicle, which uses a LOX/hydrocarbon (RP-1) first-stage engine, the RD-180, produced in Russia; and the Delta IV vehicle, with a LOX/hydrogen (LH2) first-stage engine, the RS-68, produced in the United States. The different upper stage RL-10 LOX/LH2 engines and Solid Rocket Motor (SRM) boosters for these vehicles are produced domestically. EELV costs have risen substantially in the past few years, often pricing these vehicles out of the commercial market. Commercial satellite launches have accounted for less than 20% of the EELV manifest between 2006 and 2010, and the U.S. commercial satellite industry increasingly launches its payloads on foreign vehicles, e.g., the Ariane, Proton, Zenit, and other non-U.S. systems. The reduction in U.S. domestic commercial launches has led to significant challenges for the rocket launch industrial base in this country.

Historically, NASA has launched a large number of its science missions on vehicles that have been provided by ULA, primarily on the Delta II, of Boeing (and earlier Douglas) heritage, which had launched a majority of its science missions. With the discontinuation of the Delta II, effective in 2012, it is expected that NASA must migrate its science mission needs to the higher payload capacity but more expensive EELV fleet. Given that NASA is required to launch on U.S. providers and can only barter for foreign launch services, and given the rising costs of domestic launches, obtaining future launch opportunities for NASA science missions will become considerably more complicated.

With the cancellation of NASA's Constellation Program, Congress has mandated that NASA's next heavy lift launch vehicle, the Space Launch System (SLS), must be derived from legacy hardware. In many cases this restriction limits NASA to rocket engine designs that were initiated decades ago. The situation further impacts the rocket launch industry, not only the large liquid engine companies, but also the subcontractor base and solid rocket motor manufacturers.

From NASA's perspective, beyond heavy lift requirements for deep space exploration, a replacement for Delta II capability is needed for science missions. There are similar near-term needs by the Department of Defense for a small-to-medium class launch vehicle replacement. The board heard that commercial launch systems that have the potential to help to bridge this gap include vehicles developed by Orbital Sciences, SpaceX, and others. There are considerable uncertainties associated with the reliability and long term costs for these suppliers, as well as for existing government launch services, given the current state of the rocket launch industry in the United States. The SSB spent some time this Fall discussing how it may be difficult to execute many of the missions outlined in the various NRC decadal surveys because of limited launch opportunities. The question of the cost and reliability of NASA's long-term access to space is unanswered at this time.

If I were back at NASA Headquarters, the present state of NASA science would have me thoroughly perplexed, and I can only imagine that our colleagues there who are responsible today for ensuring the success of American space science must be equally perplexed. Or more so, for they live day-by-day with stresses that a chair of the Space Studies Board can only see dimly, or not at all. But what I do see is worrying enough, or perhaps it is what I do not see that is worrying me. That is, I do not see how Congress and the Administration will decide on long-term deficit reduction and how that will mold NASA's vision of its future.

I do see that NASA's human spaceflight enterprise is in the midst of a profound transition from which it will take a decade or more to emerge, but, quite frankly, I cannot see that far. (Perhaps the forthcoming NRC study on the long-range goals of the human spaceflight enterprise will help.) Without a settled direction for human spaceflight and the public clarity that goes with it, this is bound to unsettle those planning the future of space science at NASA.

I do see that NASA will soon run out of launchers for the mid-size payloads so important to science, but I do not see what will take their place. I do see that the troubles with the James Webb Space Telescope have placed a major burden on all of NASA, but I do not see whether or when the NASA Astrophysics Division will be able to proceed with the *New Worlds, New Horizons* decadal's first priority large space-based mission, the Wide-Field Infrared Space Telescope. We had thought of it, after all, as a relatively modest technical challenge.

I do see that the Administration, wary of making new long-term commitments at a time when it knows it has to engage in deficit reduction, cancelled a well-planned joint program of Mars science with the European Space Agency. I do not see what will take its place. I do see that NASA's Planetary Science Division is engaging in discussions about a joint program with NASA's Human Explorations and Operations Mission Directorate, but I wonder whether dependence on a program whose long-term direction I cannot see is a good way to move Mars science along.

These are the big things that anyone who follows NASA can see; what about the many other smaller things that our colleagues are also responsible for? Are the big issues paralyzing creativity everywhere in NASA space science? We cannot let that happen. These big issues are slowing us down, but they are not going to stop the progress of space science. Remember that NASA, and the science and engineering community that it leads, is the greatest repository of knowledge and techniques regarding space science on the planet. Now is the time to draw on that community for inspiration and new ideas. It is, paradoxically, a time for science managers to take risks. Measured ones.

One thing I learned during my watch at Headquarters was that billion-dollar programs have a billion dollars worth of fingerprints all over them. My job was only to try to navigate such programs through seas made stormy by forces far beyond my influence. But a sum that was small to Headquarters—say $10 million—is still a lot of money and here I had discretion in how it would be spent; moreover I found that relatively small sums can have a liberating impact. Indeed, the smaller programs are one area where we can work while we wait for the big issues to sort themselves out (or not). When we do this, we pay attention to the faint first whispers of new ideas, and we seed the future.

**SPACE STUDIES BOARD NEWS**
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Two issues of interest to science are in the news as I write. One is the long-anticipated confirmation of the existence of the Higgs Boson, and with it the completion of the "standard model" of particle physics. It rated a cover on the *Economist* news magazine, where it was characterized as a "giant leap for science." By contrast, the month-long heat wave afflicting the United States, the month of rain in the U.K., and the floods in Russia are having an entirely different reception. Despite authoritative forecasts of more frequent extreme events by NOAA, the U.K. Met Office, and the UN Environmental Programme, the heat in the United States re-provoked the bitter public debate about the reliability of climate science and the ethics of climate scientists. Arguably, in 50 years time, both events will prove to have signaled profound implications for humanity, yet today one is lauded, and the other is reviled.

Since the Higgs field endows all other particles with mass, careful study of its deviations from the present standard model might begin to bridge the century-old chasm between quantum theory and general relativity and the worlds of the very small and the very large. As they have done in centuries past, observational astronomy and cosmology are again providing a fundamental challenge to physics: the present standard model has no provision for either dark matter or dark energy. No matter how they may turn out, the results to come from the Large Hadron Collider (LHC) will certainly affect, and likely strengthen, the case for space missions to study dark matter and dark energy.

No matter how different their working styles, astronomers and physicists have always had to pay attention to each other, and they need to do so more than ever. Physicists devoted $10 billion and 20 years to building the LHC, just to sort through trillions of numbers to find one number—the mass of the Higgs. It will also turn out that space astronomers will have spent almost as much and taken just as long to build the James Webb Space Telescope (JWST) to study hundreds of millions of arcane objects and, oh, by the way, maybe refine the understanding of dark matter. Physicists can easily see devoting an entire space mission to the dark energy question, just to find tiny deviations from the expansion of the universe predicted by Einstein's cosmological constant; astronomers would not willingly spend resources on it if the search did not also enable the study of hundreds of millions of objects fascinating in their own right. Fortunately, that is the case. It is now more essential than ever that NASA pursue the goals set forth for JWST and the Wide-Field Infrared Space Telescope (WFIRST) in the decadal survey *New Worlds, New Horizons in Astronomy and Astrophysics* (2010) of the Board on Physics and Astronomy and the Space Studies Board (SSB).

Why should the country, and the global community, spend so much time, talent, and money on things the people cannot see with their own two eyes? The most fundamental argument has been that advances in basic science have revolutionized society three times in the past. Newton's rational mechanics in the 17$^{th}$ century led to the Enlightenment in the 18$^{th}$; Maxwell and Faraday's electromagnetic theory propelled the second half of the industrial revolution in the late 19$^{th}$ and early 20$^{th}$ centuries; the quantum mechanics of the 1920s enabled the vast developments in information and communications technology that are changing society today. It is unpredictable, but something equally significant could emerge from the advances in physics and astronomy in the offing.

The Secretary-General of the United Nations, among others, has declared that climate change is the largest problem facing humanity in the 21$^{st}$ century. If so, advances in climate science could well have a long-term impact on society comparable with that of a major advance in basic science. Why then is its support not as consistent and enduring as that of physics and astronomy?

Twenty years ago NASA set out to create the Earth Observing System, a project comparable in scope and ambition to JWST or the LHC. This enterprise was manifestly important to society, and it was based on a new conceptual synthesis, the first comprehensive approach to understanding the behavior of Earth as a system. Twenty years later, the SSB's recent *Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey* documented a crisis in Earth observations, to the point where even optimistic scenarios of future capabilities predict that the number of missions and instruments to observe Earth from space in the next decade will fall precipitously unless existing space assets remain operational well beyond what is anticipated.

Why is NASA Earth science not achieving its goals? Many contributing factors are documented in the report but, in the end, the fact is that a cornerstone of NASA science, *despite good management of its resources*, is neither living up to its promise nor fulfilling national needs. Of the many problems facing NASA's Science Mission Division, the Earth observation crisis may be the most difficult to solve. It is

not only a question of adequate funding, although that is necessary. It cannot be solved by NASA's standard burst of inspired technology development, although that always helps. It cannot be solved by the Earth sciences alone, although they must lead. NASA cannot do it by itself, although without NASA the enterprise fails. NASA does not set its own policy, it must take national policy direction, and it has to make complex and fragile arrangements with other U.S. agencies and international partners. Indeed, several recent NRC reports, including the decadal survey and the midterm assessment, have highlighted the need for a comprehensive national strategy for Earth observations from space to better address a plethora of problems that center on the misalignment of agency roles and responsibilities with agency budgets.

Above all the Earth observation enterprise needs a stable, motivating vision like those that keep astronomers and physicists returning to the same questions for decades until they get answered. The questions for the Earth sciences are there, and the needs are there, but they have been obscured by the conflicted public debate, which is bound to affect decision making. If the Earth system science community continues to make its case, it should eventually prevail. The climate is changing, after all. Change can be unsettling at all times, and talk about changes in the Earth system tends to convey a pessimism that is at odds with NASA's "can do" optimism. However, the fundamental message is positive. Observations from space provide knowledge obtainable in no other way, which is crucial to keeping our planetary environment hospitable to advanced civilization into the indefinite future. Learning how to do this is breakthrough science. If we do break through, our children and grandchildren will have time to look up at the stars and ponder the foundations of the cosmos.

**SPACE STUDIES BOARD NEWS**
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*In lieu of his quarterly column, the U.S. Senate hearing testimony of SSB Chair Charlie Kennel is reprinted below.*

Other witnesses were Dr. Steven W. Squyres, Goldwin Smith Professor of Astronomy, Cornell University; and Mr. Jim Maser, President, Pratt & Whitney Rocketdyne. Archived webcast and statements are available at <http://commerce.senate.gov/public/index.cfm?p=Hearings>.

## Leadership in Space

**Statement of Charles F. Kennel, Ph.D.**
**Professor of Atmospheric Science and**
**Director Emeritus, Scripps Institution of Oceanography**
**University of California San Diego**
**and Chair, NRC's Space Studies Board**
**Division on Engineering and Physical Sciences**
**National Research Council, The National Academies**
**before the**
**U.S. Senate Committee on Commerce,**
**Science, and Transportation Hearing**
**The Path from LEO to Mars**
**September 12, 2012**

Mr. Chairman, Ranking Member Hutchinson, members of the committee**:**

I am Charlie Kennel, Chair of the National Research Council's Space Studies Board and a Distinguished Professor of Atmospheric Science and Director Emeritus in the Scripps Institution of Oceanography at the University of California, San Diego (UCSD). The National Research Council (NRC) is the operating arm of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology. The Space Studies Board (SSB) was established in 1958 to serve as the focus of the NRC's interests and responsibilities in space science research.

The focus of this hearing is progress in implementing the goals of the 2010 NASA Authorization Act—legislation that is clearly aimed at maintaining U.S. leadership in our exploration of space.

Two recent events remind us how important leadership is. Several weeks ago, America lost the first astronaut ever to land on another world, Neil Armstrong. Neil was respected throughout the space community, not only for his competence and his courage, but also for his modesty. He never failed to say that his success was the Nation's success. He credited it to the creativity of tens of thousands of scientists and engineers in NASA, academia, and industry and to the support of millions of the American people. He saw how an inspiring goal gets a supreme effort from the tens of thousands, and enduring support from the millions.

A little more than a month ago, *Curiosity* landed on Mars, and millions of people around the world shared its "seven minutes of terror" with the thousands who built it. This too was leadership, even though there was no astronaut on board. We are confident that *Curiosity* will carry out state-of-the-art science motivated by a very clear goal—to search for evidence of organic molecules and water, the prerequisites for life. But really, it was the audacity of the landing—the incredible sequence of things never done before that had to come out right—that marked *Curiosity* for leadership. One more time, NASA showed that when it is given something extraordinarily difficult to do, it beats the odds.

Where are NASA's next opportunities for leadership? This is a question that the Space Studies Board and our sister committee the Aeronautics and Space Engineering Board are established to help answer for the nation. Identifying the opportunities for advancing our knowledge of space through human and robotic exploration is the motivation behind the NRC's studies that the SSB and ASEB oversee.

For nearly 3 years. I served as Associate Administrator of NASA for "Mission to Planet Earth," and 12 years on the NASA Advisory Council, including 4 years as its Chair. In 2009, I served on President

Obama's Review of Human Space Flight Plans, the so-called "Augustine Commission", and since 2008 I have chaired the Space Studies Board. The views I will present today, which are my own personal perspectives, are largely informed by the work of the Augustine Commission and the Space Studies Board.

**Human Spaceflight**

As you know, the 2010 NASA Authorization Act asked the NRC to appoint a committee to undertake a study to review the long-term goals, core capabilities, and direction of U.S. human spaceflight activities and to make recommendations to enable a sustainable U.S. human spaceflight program. Following the transfer of funds from NASA to the NRC, the study commenced on August 1, 2012, and the committee recruitment process is currently underway and making good progress. Prior to the start of the actual study, a number of activities were carried out under a separate initiation task. Those activities included outreach, collection of research materials, the identification of skillsets, knowledge and perspectives critical to the study, and the broad solicitation of names as well as the review of qualifications for an extensive set of committee candidates. Outreach activities conducted in this period included a discussion session held during the Global Space Exploration Conference in Washington, DC, in which representatives from several international space agencies discussed the perspectives of their citizens and governments on the value, rationale, and future direction of human space exploration.

As recognized by the leadership of the NRC, this study embodies technical, sociological—and even philosophical—issues. The study encompasses both exceptional challenges and exceptional opportunities. Accordingly, the NRC staff who are preparing for this important activity have had an extensive series of wide-ranging discussions across the spectrum of disciplines represented in the National Academies family, as well as with the NASA community, the international community, and with members of the space community.

Once the committee holds its first meeting, tentatively scheduled for later this year, the committee will begin to solicit broadly based, but directed, public and stakeholder input to understand better the motivations, goals, and possible evolution of human spaceflight. The next task is to start to identify a set of high-priority enduring questions that describe the rationale for and value of human exploration in a national and international context. The committee has been charged to provide prioritized recommendations and decision rules that could enable and guide future planning for U.S. human space exploration. The recommendations will describe a high-level strategic approach to ensuring the sustainable pursuit of national goals enabled by human space exploration, answering enduring questions, and delivering value to the nation. Notwithstanding the considerable challenge this study represents, it is my firm belief that this committee will benefit enormously from the fact that they will have been given 22 months to complete their report, a time period that will allow them to consider carefully the difficult challenge they have been set.

In addition to the many technical studies that NASA and others have produced over the years, the study committee will also benefit from previous work by the NRC in related areas. The NRC study *America's Future in Space: Aligning the Civil Space Program with National Needs* outlines how changes in geopolitical context since the end of the Cold War are affecting the national space program and will be among the reports the new study will consider as it gets started. Our recent report *Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era* is a decadal survey recommending a research portfolio that would ensure that the Nation is ready for the next significant phase of human spaceflight. This report presents an examination of the science and technology that can bring about these achievements—such as a deeper understanding of the role of gravity in the regulation of biological systems, how to control critical fluid behavior in space exploration systems, and research on fire safety and water production in an extraterrestrial environment. The report has two foci: research that enables space exploration and research that is enabled by access to space. This is the scientific research needed to pave the way for the profoundly advanced capabilities we must have in order to make the most ambitious exploration goals not only feasible, but cost effective. The International Space Station (ISS) and its research facilities now provide an unparalleled window of opportunity to make significant and sustained progress on these questions, but this will require a full and vigorous exploitation of the Nation's enormous investment in the space station.

Virtually every NASA success has resulted from technological breakthroughs. Our NRC report *NASA Space Technology Roadmaps and Priorities: Restoring NASA's Technological Edge and Paving the Way for a New Era in Space* identifies the top 10 technical challenges as well as the highest-priority technologies for NASA missions that extend and sustain human activities beyond low Earth orbit, explore

the evolution of the solar system and the potential for life elsewhere, and expand our understanding of Earth and the universe in which we live.

Some people have said that NASA relinquished leadership of the human spaceflight enterprise when it retired the space shuttle. In my personal opinion, nothing could be further from the truth. The International Space Station, if nothing else, guarantees U.S. leadership for the rest of the decade, and there are at least three things NASA can do now to ensure leadership after that. The first is to realize the full promise of ISS utilization, building on the foundations of its status as a National Laboratory and by rebuilding the Nation's research program in life and microgravity science, as outlined in the decadal survey report mentioned earlier. Next is to encourage America's new entrepreneurial launch industry, not only to support human spaceflight and to bring down the cost to launch scientific spacecraft, but also to give a boost to an entirely new space economy. Finally, by the end of this decade, NASA has to make a firm start on a long-term program of human exploration beyond low Earth orbit. We should not minimize the challenge. First of all, it means developing a solid base of new technology and a heavy-lift launch vehicle in this decade. That is challenge enough, but human beings will have to survive away from Earth for years; the biomedical and radiation hazards must be faced, and we do not understand how we will deal with these problems. To me, the subtlest challenge of all is to learn how to sustain the enterprise for the decades it will take to accomplish its mission. This means settling on clear, fundamental goals that can endure despite the inevitable ups and downs that occur while they are being achieved.

Many people believe that Mars is the ultimate goal for human exploration, and, indeed, the 2010 Act recognizes that "*A long term objective for human exploration of space should be the eventual international exploration of Mars."* This fact alone makes it clear that NASA's Mars science and human exploration programs have a powerful mutual interest in working together. The key issue right now is to develop a clear set of goals where collaboration enhances leadership for both science and exploration. Otherwise, a relationship that has been fraught with difficulty in the past could again go awry. Fortunately, I see a new spirit of cooperation, and there is reason to be optimistic. That said, it is clear that NASA's space science program is under considerable stress. The past year has witnessed, for example, the disruption, if not outright abandonment of, scientific strategies that have been constructed over many years for the future exploration of Mars and outer planetary bodies such as Europa. And, in the process, international agreements highly advantageous to the research community, NASA, and the nation were set aside.

**Space Science**

The 2010 Act instructs NASA to take into account the current NRC decadal surveys when submitting the President's budget request to the Congress. So let me spend a little time reflecting on the current situation there.

The recently completed NRC decadal surveys and related studies, taken together, provide an up-to-date overview of the state of American space science. The study teams sought the views of their disciplinary communities by soliciting hundreds of white papers and conducting dozens of town hall meetings. The decadal survey teams included experienced managers and engineers, as well as scientists, and made independent estimates of cost and technical risk so as to make financially responsible recommendations. In all cases, however, the process started with identifying the most important scientific goals for the coming decade. Some of the financial assumptions may have been overtaken by the recent budgetary turmoil, but the goals behind the specifics still shine through. It is these I relate here, especially those whose achievement is critical to leadership in the coming decades.

American leadership in space astronomy and astrophysics is solid, but not unchallenged. The Hubble Space Telescope, the Nobel-winning Cosmic Background Explorer, and 20 years of systematically planned missions to study the sky in every accessible wavelength range, from microwaves to gamma rays, have kept research in these fields on the forefront. This leadership is ours to lose. First and foremost, we must stay the course and complete the James Webb Space Telescope (JWST). I think neither the scientific community nor Congress knew how challenging (and expensive) this mission would become, but stopping now would have serious consequences for the whole field. Many of us recall that the U.S. lost leadership in particle physics to Europe when the Superconducting Supercollider was cancelled. We cannot let the same thing happen to JWST, which will do in the 21st century what Hubble did in the 20th. Next, we should capture the benefits of pioneering American breakthroughs in dark energy by accomplishing the goals of the Wide-Field Infrared Survey Telescope (WFIRST), the first priority mission in the NRC decadal survey *New Worlds, New Horizons* and a highly capable mission that has an equally compelling science goal in the discovery of extrasolar planets. Completion of JWST may delay

their accomplishment, but if we do not pursue Earth observation enterprise needs the country to agree on a stable, motivating vision like those that keep astronomers and physicists returning to the same questions for decades until they get answered.

Planetary science is leadership science in its essence. Simply getting to another planet is a major challenge, and landing on one is where the United States is a complete master, as *Curiosity* shows; the U.S. is also the undisputed, but not unchallenged, leader in the orbital exploration of the outer planets and their satellites. My colleague Steve Squyres can make these points with much more authority than I, since he chaired *Vision and Voyages,* SSB's recent decadal survey in planetary science. Here I restrict myself to a few general remarks. His committee's report identifies the highest-priority mission being one that would begin the process of returning samples from Mars. The report emphasizes the importance of maintaining a balanced program and describes promising smaller missions and the supporting activities necessary to make these programs successful with strong support for the New Frontiers and Discover classes of missions. Many people have praised *Vision and Voyages* for its succinct set of "decision rules" designed to help cope with changing budgetary circumstances.

*Curiosity*, because it has a long-lasting nuclear power source, could produce world-class science throughout the coming decade, but unfortunately there is now a question of what comes after that for Mars. *Curiosity* is the product of a program strategy developed in the late 1990's to answer a first-class scientific question: What did water on Mars do in the past, and where is it now, and is there evidence for organic molecules? (Water and organic molecules were, after all, the prerequisites for life on Earth). Recently, the next two missions consistent with this strategy—The Mars Trace Gas Orbiter and the Mars Astrobiology Explorer-Cacher— were cancelled; whatever the issues of risk and financial prudence that might have motivated this decision, it sends a chill through the Mars science community and its many followers in the public. The near future looks bright, but what will come after the launch of MAVEN1 in 2013 and InSight2 in 2016? Will we be able to keep the team together? Fortunately, *Visions and Voyages* points to a guiding direction for Mars science exploration. Missions should contribute to the goal of sample return, so that one day hundreds of scientific laboratories on Earth can be put to work broadening the scientific beachhead our landers are occupying.

NASA has assembled an internal team to identify an integrated strategy for the agency's Mars Exploration Program in light of current funding constraints. NASA has said that team's initial focus will be on a possible 2018-2020 robotic mission as part of a program whose framework will be developed in consultation with the science community and international partners, and which aims to advance the priorities in the *Vision and Voyages* decadal survey. This team's report is expected to be released soon, and we at the SSB with our Committee on Astrobiology and Planetary Science stand ready to assist in ensuring that the eventual program pursues the carefully developed priorities of the decadal survey—priorities that are the result of a 2-year process that represents the

consensus position of the scientific community on a balanced planetary science program that will produce, as Steve Squyres has said many times, the best science return per dollar for the Nation.

I have highlighted where I see opportunities for leadership in each of NASA's main areas of space endeavor. I have had to gloss over the many other less visible, but in total equally essential, activities that contribute to excellence. These may be found in the reports themselves. But there is one more requirement for leadership that can be found in every report: *balance*. Balance means different things in each area, but basically it means that we should not put all our eggs in one basket. Also, balance definitely does not mean "something for everybody!" Smaller spacecraft missions, sub-orbital flights, modeling, data analysis, and research grants sustain the quality of the disciplines that originate the great leadership projects. It is striking to me that each of our committees put its recommendation for balance on an equal footing with its first-priority leadership mission.

What does this mean for you as legislators? Keep in mind that when you support leadership projects, you are investing in the spirit of innovation, and when you support balance, you are investing in the capacity to innovate.

Never before has congressional leadership been more critical to America's leadership in space than now. Now is the time for you to shape enduring goals that can guide America's space program to its next stage of leadership in the complex times you see ahead. The space science and technology community can deal with budgetary turbulence, but only when there is a stable sense of direction.

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1 Mars Atmosphere and Volatile Evolution, the second and final Mars Scout mission.

2 Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, the next Discovery mission.

**SPACE STUDIES BOARD NEWS**
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***This quarter's article is provided by the Co-Chairs of the Lessons Learned in Decadal Planning in Space Science Workshop Organizing Committee, SSB Chair Charlie Kennel and SSB Member Alan Dressler.***

Between 2010 and 2012, the National Research Council completed four decadal surveys—in astronomy and astrophysics, planetary science, solar and space physics (heliophysics), and life and physical sciences in space. The SSB also completed a decadal midterm review on Earth sciences and applications from space. Taken together, these may comprise the most complete characterization of the state of the space sciences ever achieved. Yet, when the surveys arrived on NASA's doorstep, NASA found it difficult to implement recommendations that it anticipated it could when the surveys commenced their work.

What happened? How can we improve the next time around? These were the central questions motivating the "lessons learned" workshop convened by the SSB and Board on Physics and Astronomy on November 12-13, 2012. Some 150 participants from the domestic and international Earth and space science communities debated all aspects of the decadal review process: how the community reviews its past achievements; how it characterizes its present status and identifies future opportunities; how scientific ideas are shaped and reshaped by committee debate into "placeholder" mission and program concepts; how technical challenges are identified and conservative costs estimated; how cost and technical evaluations influence scientific choices and the committee process; how the survey committees interact with NASA and the scientific community during the study phase; what role international and interagency collaborations play in shaping recommendations; and above all, how to cope with policy fluctuations and budgetary uncertainty.

Uncertainty was the elephant in the room. It permeated all of the discussions at the workshop. The recent budgetary turmoil and a succession of continuing resolutions has given Congress little opportunity to express tangibly its goals for space science and exploration. There is pervasive uncertainty about the long-range direction of the federal funding for science, and this has discouraged policy initiative. Neither those who give advice nor those who receive it have a clear grasp of what the future holds, a reality for NASA that was underscored in the recently released report *NASA's Strategic Direction and the Need for a National Consensus* (NAP, 2012). The report, carried out under the auspices of the SSB's parent Division on Engineering and Physical Sciences but organized by SSB and ASEB staff, concluded that: "There is no national consensus on strategic goals and objectives for NASA. Absent such a consensus, NASA cannot reasonably be expected to develop enduring strategic priorities for the purpose of resource allocation and planning."

In such a circumstance—unprecedented in our experience—we were asking how we can shape our advice so that it preserves scientific value and remains resilient to budgetary instability. Can we craft "decision rules" that help NASA cope with downstream policy turbulence? How do we provide ongoing advice between decadals? What role do the SSB's standing committees, as stewards of the decadal surveys, play in that respect? Over the long history of the space program—until recently—the partnership between SSB and the NASA Advisory Council helped promote flexible NASA responses to the SSB's long-term advice. Can we rebuild the SSB's long and once productive working relationship with the NASA Advisory Council?

NRC reports are notable for their rigorous review; the most rigorous part of the review is to ensure that no report strays beyond its statement of task (SOT). As a result, nothing is more important to success than getting the SOT right. The SOT defines what issues shall be studied, how they shall be studied, and how they shall be described. The SOT negotiations between the NRC and NASA aim to develop a common understanding of terms of art that might otherwise be misinterpreted, including clear definitions that build understanding among the other stakeholders in the decadal surveys—OMB, OSTP, and Congress. There was a strong sense at the workshop that the next time around, the SSB ought to enlist broader community input before the SOT is set in stone. In the words of one participant: *"It's the statement of task, stupid!"*

Highlights of the presentations and discussions illustrate the breadth and depth of the program. The workshop began with a sober reflection by former SSB Chair and past NASA Associate Administrator (AA) Len Fisk, who pointed out that the principle that governed the conduct of the nation's space science program for the first 35 years of NASA was this: the National Research Council does the planning, and the NASA science program is conducted on behalf of the all of the nation's space scientists. However,

during the past 20 years these principles have been challenged and at times disavowed. And throughout this past 20 years, the management structure by which NASA executes its science missions has been weakened.

The next session called upon past decadal survey chairs to reminisce about the surveys they led (what in corporate culture are called "war stories"); specifically, what worked—or did not work—well, and emphasizing the value of this unique activity that probes the collective will of an entire discipline community. An NRC staff presentation on the specific organization plans for recent decadals in Earth science and applications from space, astronomy and astrophysics, planetary science, and solar and space physics showed how their different scientific cultures necessitated tailored approaches to their surveys; for example, the "solar-system-target" program of planetary science, the "physical-process-and-system" focus in both heliophysics and Earth science, and the multicomponent program of astronomy and astrophysics with its myriad of cosmic 'residents' and phenomena. Given this variety, it is gratifying that the NRC's strategy for decadals works well for all.

The sessions on program formulation and the role of the cost assessment and technical evaluation (CATE) process delved into the nuts-and-bolts of the decadal survey process. Attending discipline division directors (or their alternates) from within SMD floated the possibility of "science-only" prioritization; an approach they felt would be more robust to changing technical and budgetary realities throughout a decade. However, the scientists with experience in the prioritization process vigorously contended that the definition of representative missions capable of carrying out the science—even conceptual and immature—were essential in the exercise. These NASA representatives also argued that defining accurate cost estimates for pre-phase-A missions was not realistic and expressed the concern that the CATE process had taken on too much importance in the most recent round of decadals. The NASA officials contended that approximate "boxing" of notional missions into 'small, medium, and large' categories would be sufficient and probably better for program formulation. Despite lively discussions of the strengths and weaknesses of the CATE, including standards, feedback, and the role of iteration, workshop participants who were involved with recent surveys said that introducing *non-advocate* cost estimates into the process had been a success and should be retained in some form as an essential facet of all future surveys.

NASA management's seeming preference for "science-only" prioritization spurred discussion of the possibility of decoupling a decadal survey's science prioritization phase from the mission formulation phase; in effect, creating two separate processes—perhaps undertaken by different committees—as opposed to the traditional survey's integrated program-formulation process. This would be a substantial departure from current NRC practice and likely have significant ramifications on cost and schedule for both the decadal surveys themselves and the recommended programs.

The concluding sessions of the workshop covered, among other things, the question of whether high-profile missions such as James Webb Space Telescope and Mars Science Laboratory (the *Curiosity* rover) require special treatment by the decadal surveys and NASA—if this is even desirable, and how choices for such elevated status could be made across the disciplines. An important and thoughtful discussion of the increasingly important aspect of international collaboration highlighted some of the challenges in aligning and/or coordinating independent and rather different prioritization processes of the European Space Agency and the Japan Aerospace Exploration Agency. The attendees expressed admiration and satisfaction for the degree and quality of international collaboration on major space missions and the willingness of all involved to overcome the problems that international partnerships can encounter. Nevertheless, participants on the international panel posited that this is a major deficiency in the space science planning apparatuses currently in place.

In retrospect, the workshop could have gone on productively for another day. Participants were as engaged at the end as they were at the beginning and, throughout, earnest in the task. In fact, in our opinion each of the workshop's seven panels generated sufficient new ideas and suggestions to warrant exploration in the content of a follow-on study. Yet, beyond all the constructive suggestions, the most important thing was something we did *Not* hear: *The SSB should never do another decadal survey again.* We heard instead that decadals were unequivocally worth the effort, but that they could be made perhaps simpler and more resilient.

Although the workshop represents a first step in improving the decadal survey, it was a notable exercise in its own right for bringing together all of the stakeholders involved in this worthy effort and fostering interactions amongst groups and individuals who might not get the opportunity to talk to one another. We are all looking forward to the release of the workshop summary report this upcoming spring.

**SPACE STUDIES BOARD NEWS**
**VOLUME 24, ISSUE 1 January-March 2013**

The Space Studies Board convened a meeting of its standing committees on March 8 and 9 of the first of what we hope will be an annual tradition—the NRC's Space Science Week. All four SSB standing committees met in the newly refurbished National Academy of Sciences building on Constitution Avenue in Washington, DC. The session was well attended by our NASA and other federal agency colleagues; John Grunsfeld, the Associate Administrator for the Science Mission Directorate, the leaders of all four NASA science mission offices, and representatives from several other agencies—including USGS, NOAA, and NSF— participated in our discussions. All had hoped that the Administration's budget would have been released by that time, so that our committees and government leaders could consider together its implications for space science. That was, of course, not to be, but we can hope that next year will be different.

There was a hidden bonus, however, as the standing committees had a greater opportunity to discuss new developments in science as well as longer-range policy issues. Of special interest to me were the interdisciplinary sessions, which would not have been possible unless we had convened all the standing committees at the same time in the same place.

The Committee on Astronomy and Astrophysics (CAA) and the Committee on Astrobiology and Planetary Science (CAPS) met together to discuss the exciting discoveries of Earth-like planets by Kepler. It was clear to this observer that a rich new multi-disciplinary research agenda demanding knowledge and techniques from astrophysics, planetary science, and astrobiology is emerging rapidly. Stay tuned; I hope and trust that SSB can play a constructive role in working with NASA leadership to connect these research programs in a forward-looking way.

The Committee on Solar and Space Physics (CSSP) and the Committee on Earth Science and Applications from Space (CESAS) met together on a policy issue of mutual concern: how best to work with the research to operations transition with NASA's sister agencies, NOAA and USGS. Research projects in both space physics and Earth science now develop useful applications during the conduct of the missions themselves, and it is important to ensure that the societal value of NASA research be realized as promptly as possible.

CESAS also spent an entire day working with Mike Freilich, Director of the NASA's Earth Science Division, to design a potential study of "continuity measurements" for which it is important to provide resilient data streams to practical and policy users as well as researchers. Our "lessons learned" workshop had emphasized the importance of designing the statements of task of our studies, and I felt this was a constructive use of standing committee time. The other standing committees also strengthened their working relations with their corresponding research divisions at NASA, and I consider the improvement in mutual understanding during a difficult time for NASA to be a very important intangible outcome of the first NRC Space Science Week.

On March 18 and 19, Michael Moloney and I put in invited appearances at the 51st Annual Goddard Symposium in Greenbelt, Maryland, a "gathering of the clan" for many in NASA and industry involved with NASA projects. Two things made this year's meeting notable. First was the impact the so-called "sequester" is having on NASA. Extreme travel restrictions dramatically limited the attendance of NASA personnel at what is traditionally one of the more important meetings of the year for NASA; even attendance from Goddard Space Flight Center, just down the road from the conference venue, was limited. The second interesting feature was how much the influence of the SSB and the Aeronautics and Space Engineering Board on NASA programs was referred to by different speakers. I could not help but connect the two in my mind. It is clear that NASA is going to have difficulty convening its own scientists to get the advice and program guidance it needs. If this continues for a long time, it could become a profound threat to the excellence and timeliness of NASA science. The SSB and its standing committees cannot replace the missing advice and guidance, but we hope we can help our NASA colleagues out. We have decided to hold as many of our meetings in Washington, DC, as possible until NASA's travel restrictions become less onerous. NASA will, perforce, hold many more of its meetings electronically, and we hope NASA will also feel free to ask the SSB and standing committees to convene electronic meetings when they need to keep everyone up to date.

**SPACE STUDIES BOARD NEWS**
**VOLUME 24, ISSUE 2 April-June 2013**

Recently, a number of colleagues have expressed to me the worry that "Our scientific advice is not getting through." It is hard to know precisely what to make of this, though I suspect there is a kernel of truth in there. Certainly, you have only to read the newspapers to know that the political divisions in our nation's capital have altered the once familiar ebb and flow of power and ideas between the administration and Congress. This is unfamiliar territory, so it is hard for us to perceive why things happen as they do—or not. Our colleagues who manage NASA's science program must also be finding themselves in uncertain terrain. Maybe they are less open to listening to new ideas from the science community because they are concentrating on getting the present job done. In the present circumstance, this is necessary and admirable, but it could leave us with the impression that they aren't listening. My guess is that they are listening and wish they could respond.

A more dire version of the same complaint is "Our science advisory apparatus has broken down." There may also be something to this. Our "Lessons Learned in Decadal Planning in Space Science" workshop last November was devoted to understanding why NASA gave such an uncertain reception to the Space Studies Board's recent decadal surveys. Both NASA and the SSB believed the surveys were realistically designed when they began. There was a key breakdown, however. Both government and National Research Council (NRC) rules impeded the flow of information between NASA and the SSB during the conduct of the surveys. Our standing committees had stood down, so just as several critical situations emerged, our science communities were tied up writing decadal surveys—which they could not discuss with anyone until they had gone through NRC review. Just when our colleagues in NASA's science division wished they knew how the SSB would react, they could not tell us of their problems, and we could not tell them what we thought. Nor was the NASA Advisory Council (NAC) Science Committee as able to help as much as before; it was essentially disbanded in 2006. Both of these problems have been ameliorated. Our standing committees are up and running, and we hope to establish one devoted to life and microgravity sciences shortly. The NAC Science Committee was successfully rebuilt under the leadership of Wes Huntress, and NAC Chairman Steve Squyres and I have agreed that we must work together more closely in the future. It only makes sense. SSB's role is strategic; NAC is positioned to give NASA an ongoing stream of tactical advice.

The SSB and NAC are not the most important ways NASA gets technical advice. That comes from NASA's own scientists and engineers. I worry that the travel restrictions placed upon on all NASA personnel by the recently passed budget sequester will greatly limit the value of the advice NASA gives itself. It is not just that fewer NASA scientists can go to professional meetings, they will also be less able to visit their colleagues at other NASA centers or go to headquarters to work with their program leaders. These exchanges are the lifeblood of NASA, and one can only hope the travel restrictions will not last a long time. In the meantime, these circumstances place a great responsibility on the SSB and NAC, who still have the ability to convene groups to give NASA expert advice.

It is incumbent on both the SSB and NAC to build closer relationships with our NASA colleagues. SSB will hold most of its meetings in Washington, DC, for the foreseeable future. Our committees are making much more frequent use of conference calls and WebEx meetings, which are enabling more frequent contact with NASA. And then there is NRC's "Space Science Week," which brings all of our standing committees together at one time. Our first one in March of this year was a great success; people appreciated the opportunity to interact with their colleagues in other space disciplines, and I am sure this will lead to a more interdisciplinary approach to the definition of long-term science goals.

I have high hopes for Space Science Week's future. This is a time when we can not only reach out to our NASA colleagues but also to congressional staff and administration leaders who we hope will sit in. Next March, and hopefully every year from now on, we will invite foreign colleagues to brief our committees on their programs so that when decadal survey time comes around again, the U.S. space science community will be better informed about the prospects for international collaboration. We are planning a public lecture by a leading space scientist to share our vision of the future of space research with a wider public.

I hope that, eventually, the whole space science community will see Space Science Week as the time when the next year's agenda can be debated. I hope that Space Science Week can be coordinated with a spring NAC Science Committee meeting whenever feasible. I hope that industries interested in space science will find it valuable to attend. I hope that individuals will choose Space Science Week as a good

time to communicate with Congress. But these hopes are in the hands of my successor, because my term of office reaches its statutory limitation next July 1.

I have high hopes for my successor. Stay tuned.

**SPACE STUDIES BOARD NEWS**
**VOLUME 24, ISSUE 3 July-September 2013**

As I write, we are several months into the budget sequester, 16 days into the government shutdown, and 12 hours before default on U.S. government debt, with no real resolution in sight to the basic political conflict underlying this impasse. The impact of the shutdown on NASA's day-to-day operations is almost total. Ninety-seven percent of NASA's workforce is on furlough, and NASA's contractor workforce faces an uncertain fate. NASA's websites are down, and researchers all over the world are unable to access NASA data; fortunately, NASA is allowed to keep the astronauts and cosmonauts healthy and active on the International Space Station.

The shutdown will end, but the loss of productivity only makes it all the more difficult to sustain U.S. leadership in space, which was hard enough already given the ongoing effects of flat budgets and sequestration. Even before the present paralysis took hold, NASA was slowly being deprived of oxygen as the conflict over basic political principles reached down to enervate the government's lower levels. Now, you cannot be part of the government without political considerations affecting how you carry out your mission. It has always been important for NASA leadership to respond to the goals of the Administration and Congress. But, at the end of the day, people on both sides of the aisle believed that science—space science—*ought to be* non-political, an attitude that led to some restraint. I wonder whether this is true anymore. I have recently encountered two different political visions of what science NASA should be pursuing. If this continues, there could be real problems. Even the espousal of two scientific visions creates problems in today's conflicted atmosphere. How should NASA's managers navigate between a Republican Scylla and a Democratic Charybdis? Will their programs change dramatically each time an election alters the dominant political philosophy? This is not good for an agency whose projects take years to bring to fruition.

Politicization of science could be one of the more serious fallouts of today's governmental crisis. What can we do in such a circumstance? Before things go too far, I believe it may be time for the National Academies and other professional organizations to reaffirm the authority of science over the goals and findings of scientific research. We on the Space Studies Board have a responsibility to convey the impacts on space and Earth science of policies proposed, actions taken, and opportunities missed, as well as to identify new opportunities. We can be politically aware, but people only listen when we talk about science. What can we say?

American space science leads the world because it has concentrated on fundamental scientific issues. This cannot be said too many times.

**SPACE STUDIES BOARD NEWS**
**VOLUME 24, ISSUE 4 October-December 2013**

This spring, the Space Studies Board (SSB) and the Aeronautics and Space Engineering Board will together inaugurate a new standing committee, the NRC's *Committee on Biological and Physical Sciences in Space (CBPSS)*. The new committee will not have much time to get its bearings, for odds are it will find itself faced with challenging issues from the get-go. Though its remit extends considerably beyond the International Space Station (ISS) science, one of the first questions it may be asked will be about the scientific implications of President Obama's recent decision to extend the Station's life from 2020 to 2024.

As many of you may recall, in 2009 the Augustine Commission (on which I served) recommended, and the President decided, that the Station's life be extended from 2015 to at least 2020, with the actual termination date to be decided later. One of the last Shuttle flights brought up to ISS large replacement parts that could not be carried by the smaller supply flights to follow. Science was not the sole reason for the ultimate decision on whether to extend the life of the International Space Station, but it will play an important role in the success of ISS operations. The central question will be, what are the likely benefits to U.S. science and technology of the four-year life extension? In other words, can we extrapolate from present experience and reasonable expectations what four years more work might achieve? How can the life extension incentivize new researchers with new ideas to take advantage of ISS access to low gravity, the space environment, and its vantage point in the heavens? How should the total of ten years' more operational, technological, and medical experience contribute to the goal of exploration beyond low Earth orbit?

One can easily think up other equally interesting questions. My point is that it will be very hard for the U.S. ISS science community to answer the questions put to it, because of its lack of recent experience. The U.S. life and microgravity science community that had conducted research on Shuttle, and later ISS, was scattered to the four winds in the middle of the last decade. In the FY2008 NASA Appropriations Act, a concerned Congress asked the NRC for the first-ever decadal survey in this field, *Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era (2011).* This decadal survey focused on identifying the most relevant and valuable topics of research in low gravity, the criteria by which NASA could best prioritize that research, and the agency's support structural elements—such as an active research community—that would be required in order to meet NASA priorities.

NASA has responded constructively, notably creating a new division to oversee and consolidate the direction of low gravity research, and there has been a definite uptick in ISS scientific utilization. Nonetheless, it will be necessary also to feature the results achieved by the international partners, who provided more consistent support for their science programs on ISS. Even so, extraordinary scientific, technical, and programmatic judgment will be required to create an achievable first-class program. Besides scientific prognostication, there will be numerous non-scientific imponderables. For example, today's ISS-related programs and those after 2020 may not have the same scale; there could indeed be a greater scope for science and technology then; or the difficulties of operating an aging system could take away from science and technology, despite the best intentions.

Why should the Earth and space science community consider ISS life extension a major concern? The answer lies in the history of Shuttle and Station science advocacy. Many of us believe that science was oversold in the early advocacy for the International Space Station. The question about the potential value of science aboard Station was asked then, and a chorus of advocates answered it. Many people at that time may have gotten the impression this chorus represented the expert community. However, the scientific community responsible for actually doing the work when formally consulted—for instance, by a series of SSB reports— provided a more measured and cautious assessment of the scientific potential of Station. It is important to note that many of the conditions they cited as important for fulfilling Station's considerable scientific potential have been met only recently, or have yet to be met.

The establishment of an advisory structure for NASA's Space Life and Physical Sciences Research and Applications Division both within the NASA Advisory Council and at the NRC provides two important forums for debating future Station science. This debate would benefit greatly from an organized formal evaluation. We at the Space Studies Board stand ready to contribute.

**SPACE STUDIES BOARD NEWS**
**VOLUME 25, ISSUE 1 January-March 2014**

I chaired my last Space Studies Board (SSB) meeting on April 3 and 4, and attended my last meeting as an *ex officio* member of the NASA Advisory Council (NAC) on April 16 and 17. These were wistful moments for me. I had served on the NAC from 1998 to 2006, chairing it between 2001-2005; after 2006, there was a two-year hiatus, during which I co-chaired the NRC's Beyond Einstein Program Advisory Committee (BEPAC), and then my NAC membership resumed with my SSB appointment in 2008. I had also served on the review of U.S. Human Space Flight Plans Committee (the so-called Augustine commission) in 2009. So you can see much of my later life has been bound up with volunteer work providing advice to the U.S. Space Program.

It is certainly well past time that NASA and the NRC heard from somebody new about the space sciences. But I cannot help but think back. I wake up some nights thinking of mistakes I may have made, opportunities I did not see, of colleagues I underestimated, of contributions I did not acknowledge. I will never be an objective judge of my sins of omission and commission; others will have to make that judgment. Nor can I be an objective judge of the accomplishments of the SSB on my watch. Others will have to make that judgment, too. I can be a reliable witness only to what I am thinking about at this very moment, this fleeting instant of time.

I can tell you what I am happy about.

I am happy about the optimistic and confident NASA that I have seen emerge in recent months. Part of it is that NASA has a budget for a change. Not that it is perfect, but it does the job and NASA can plan, knowing they have the confidence of the Congress and Administration.

I am happy about how NASA, led by Bill Gerstenmeier (Associate Administrator for Human Exploration and Operations), is conceptualizing its human spaceflight future, laying out a building-block approach to landing humans on Mars sometime in the future. If we are willing to wait and overcome challenges one by one, it need not require a huge infusion of new resources. For the first time, I begin to believe that it might actually be possible.

Having served on the Augustine commission, I am happy that NASA's decision to support new entrepreneurial space launch companies seems to be bearing fruit.

I am happy about the explosion of exciting results on extrasolar planetary systems, and all the implications for how we humans view our existence. I am happy that astrobiology is recovering from its budget cuts of a few years past. I am happy that I was at JPL when *Curiosity*, the Mars Science Laboratory, made its daring landing; SSB's executive committee met there right afterwards. I am happy to know there is abundant evidence that water has played a significant role in shaping the martian environment and that the Moon is not as dry as we previously believed. I am happy that NASA's heliospheric physics program has developed so much maturity and competence in its observations and models that it is supporting the creation of a practical national space weather program. I am happy that NASA Earth observations continue to provide more and better observations about the Earth system than the rest of the world combined, as it has since the days of the Earth observing system in the mid-1990s. I am happy that there have emerged no more major problems with the development of the James Webb Space Telescope. I am happy that NASA seems to be finding a way to accomplish the goals for dark energy space research that were set forth in the SSB's decadal survey for astronomy and astrophysics.

I am happy with the Space Studies Board.

I am happy that the SSB's decadal surveys remain one of the finest examples of rigorous scientific planning anywhere. I am happy that SSB's 2012 "lessons learned" workshop stimulated so much deep thought about the next round of surveys.

I am happy with how the SSB and the NRC Board on Physics and Astronomy collaborate to sponsor the Committee on Astronomy and Astrophysics, which surveys both space-based and ground-based programs. I am happy that SSB reconstituted all its standing committees after some of them had stood down during the writing of the most recent set of decadal surveys that took place on my watch. I am happy that the SSB worked with NASA and NRC leadership to furnish our standing committees the flexibility to build the organic relationship with NASA's program offices that I had long dreamt of.

I am happy with the two NRC Space Science Weeks the SSB and BPA has sponsored thus far, when our standing committees met together in parallel and joint sessions. I am happy to have participated in their discussions. I am happy with the idea that the NAC's science committee might join us during Space Science Week next year.

I am happy with the SSB's partnership with the Aeronautics and Space Engineering Board (ASEB). I am happy with my relationship with its chair, the great General Lester Lyles. I am happy that our two boards will co-sponsor a new standing committee on biological and physical sciences in space. I am happy that NASA's Human Exploration and Operations Mission Directorate supports the new committee. I am happy that our two boards did much of the thinking behind the design of the Committee on Human Spaceflight. Its report will be released soon, and I believe it may well prove to be the most influential one that will have been completed during my time with the SSB.

I am happy with the support the NRC leadership has given the SSB, from working with SSB and NASA to redesign our standing committees, to supporting, with private National Academies funds, our forthcoming Forum for New Leaders in Space Science, joint with the Chinese Academy of Sciences.

I am extremely happy with the SSB's staff. Each is an expert in the policy of his or her field. In fact I believe that the SSB and ASEB jointly are now the most knowledgeable independent group providing advice about America's civil space program. The staff holds it all together. They are the SSB's institutional memory.

I am exceptionally happy with the creative way Michael Moloney has led that staff. I am happy to have seen him evolve into a policy leader in his own right—with NASA and within the NRC.

Most of all, I am happy with the NRC's choice of David Spergel as my successor. He is a world-class theoretical astrophysicist with fine organizational instincts and great energy.

I am happy David will be writing the next Chair's Column.

One thing makes me unhappy: the thought of not seeing so frequently the extraordinary individuals who serve on the Space Studies Board.