

**LEADERSHIP IN SPACE**

**Statement of**

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**Division on Engineering and Physical Sciences**

**National Research Council**

**The National Academies**

**before the**

**Committee on Commerce, Science, and Transportation**

**U.S. Senate**

**Hearing on**

**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 21<sup>st</sup> century what Hubble did in the 20<sup>th</sup>. 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

these goals in as timely a manner as possible, we lose our edge. Europe will launch a dark energy mission in this decade.

Heliospheric physics, the field in which I started my career, is the most mature branch of space science. In the past 20 years it has achieved a precision of measurement and modeling that astounds me and puts the field on the threshold of transformative advances in its understanding and prediction of “space weather.” We now can predict in detail when and how events on the Sun will affect the operation of technological systems that are sensitive to Earth’s electromagnetic environment, like electrical power-grids, pipelines, and communication satellites. Congress has a delicate role to play here, as it guides the evolution of this new research-intensive operational program, since relationships among NASA, NOAA, and DOD need to be shaped. Leadership in science does not always mean big missions, it can also mean innovation in program design and integration. Here the SSB’s most recent decadal survey, *Solar and Space Physics: A Science for a Technological Society*, excels. Its DRIVE (Diversify, Realize, Integrate, Venture, Educate) initiative proposes a mix of orbital and sub-orbital missions, modeling, and ground-based measurements that is both scientifically innovative and fiscally realistic. Later in the decade a set of moderate missions will enable a set of compelling science targets that the survey identifies as key to advancing our understanding of the complex system that encompasses the interactions of the Sun with our home on Earth, its planetary environs, and the surrounding heliosphere—the outer edges of which are being explored now by the Voyager spacecraft 35 years after their launch.

Earth science, the field in which I was once NASA’s Associate Administrator, staked out a position of undeniable leadership in the 1990s that could be lost in the next decade unless some firm directions are set. Twenty years ago NASA began the Earth Observing System, a project comparable in scope and ambition to JWST and *Curiosity*. This project 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. Now, 20 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. We are now at 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. 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 the resources it has*, is neither living up to its promise nor fulfilling national needs.

NASA cannot solve the crisis in Earth observations by itself, although without NASA the enterprise fails. In this field, NASA needs to take a national approach, 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 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 MAVEN<sup>1</sup> in 2013 and InSight<sup>2</sup> 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

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<sup>1</sup> Mars Atmosphere and Volatile Evolution, the second and final Mars Scout mission.

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

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.