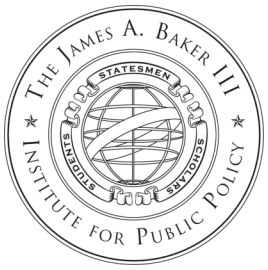

James A. Baker III Institute for Public Policy
Rice University

Maximizing NASA's Potential in Flight and on the Ground: Recommendations for the Next Administration

By

George Abbey

Baker Botts Senior Fellow in Space Policy
James A. Baker III Institute for Public Policy
Rice University

Neal Lane, Ph.D.

Senior Fellow in Science and Technology Policy, James A. Baker III Institute for Public Policy,
and Malcolm Gillis University Professor, Rice University

John Muratore

Adjunct Lecturer,
Department of Mechanical Engineering and Materials Science, Rice University, and
Research Associate Professor, The University of Tennessee Space Institute

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Overview

The new administration presents NASA with a unique opportunity. Instead of trying to close the gap in human spaceflight, and continuing to exhaust critical resources on the current Vision for Space Exploration, NASA should dedicate itself in the first term of the new administration to proving its relevance in the post-Cold War world while restructuring its human spaceflight objectives. We propose a new direction for NASA, a five-point plan that can be carried out with existing capabilities and realistic budgets:

1. Restructure the human space initiative and keep the space shuttle flying until 2015.
2. Deliver short-term (within four years) payoffs in energy and the environment, especially climate change.
3. Deliver longer-term payoffs (within four to eight years) for energy and the environment.
4. Ensure an ongoing and effective robotic space science program.
5. Implement a reinvigorated and effective aeronautical research program, with particular attention to low-carbon fuels and efficiency, to help ensure the future well-being of the nation's aviation industry.

Background

On May 25, 1961, President John F. Kennedy challenged the nation to send a man to the moon and return him safely to Earth by the end of the decade. If accomplished, the feat would clearly establish the United States as the world's technological leader. The Apollo program, which will go down as one of the greatest achievements of all time, was on its way. In little more than seven a half years, *Apollo 8* orbited the moon and seven months later, *Apollo 11* landed on the lunar surface. The Apollo program captivated the imaginations of literally thousands of young people who went on to become the nation's scientists, mathematicians, and engineers—a brain trust for U.S. industry that fueled American progress for decades.

The United States has continued to maintain a proud record of leadership in space with both manned and unmanned orbital and exploration missions. The successful Viking spacecraft

landings on Mars provided the most complete view ever of the planet. Volcanoes, lava plains, immense canyons, cratered areas, wind-formed features, and evidence of surface water were all apparent in the Viking orbital images. The exploration of the "red planet" continued with the *Mars Pathfinder* and *Sojourner*, and the very successful Mars exploration rovers, *Spirit* and *Opportunity*, have continued to provide useful data on the planet almost continuously since 2003; these and other planetary and astronomy missions, such as the Hubble Space Telescope, have completely changed our understanding of the universe in a human life span, and have been equaled by orbital missions that have helped us to better understand Earth and our environment.

The U.S. shuttle transportation system is the longest running, most successful fleet of manned space vehicles ever produced. The International Space Station (ISS), which involves close partnerships with Russia and 16 other nations, is an incredible accomplishment. When completed, it will represent the largest international cooperative technological project in history.

In 2004, President George W. Bush chose to establish a new course for NASA and the civil space program. He announced his Vision for Space Exploration (VSE), a bold plan to complete the ISS and phase out the space shuttle by 2010. Under the VSE, a replacement for the space shuttle was to be designed and built by 2008 and flown by 2014. Humans would return to the moon by 2020 and prepare for missions to Mars. It was made clear that VSE was to be led by the United States.

With President Bush's new vision in mind, NASA quickly reset its priorities. Going to the moon and Mars became the agency's mission. The new priorities pushed science, environmental, and aeronautical research further down the list, and international cooperation was no longer encouraged. Space domination emerged as the administration's space policy, and that agenda did not have a place for cooperative activities in space.

President Bush presented a bold vision, but as several critics pointed out at the time, the vision was incomplete—there was no detailed plan, no provision for the transport of astronauts to space after the shuttle phase-out, no consultation with foreign space partners, and science was no longer a priority.

It's been said that vision without funding is a hallucination. No cost estimates were presented for returning humans to the moon and to Mars. The first part of President Bush's vision, as proposed, was to be funded by adding $1 billion to the NASA budget over five years, and reallocating $11 billion from within the NASA budget during the same time frame. These amounts were within the annual 5 percent increase the Bush administration planned to add to the NASA base budget (approximately $15 billion) starting in fiscal year 2005. This budget, however, was very small in comparison to the cost of going to the moon with the Apollo program. The cost of the Apollo program was approximately $25 billion in 1960 dollars or $125 billion in 2004 dollars, and the objectives of the NASA Plan are, in many ways, no less challenging. Former senator John Glenn has called the Bush VSE program "one of the biggest unfunded mandates that we have had in all of government history."

Actions initiated as a result of President Bush's new vision have confirmed the lower priority for scientific research, especially efforts to use space to better understand the Earth's environment. They have also seriously damaged international programs such as the ISS. Now that the Europeans and Japanese finally have research modules installed on the station, and can gain a return on their substantial investments, their planned research is in jeopardy. The United States has arbitrarily decided to end support of the space shuttle (with its critical up-and-down mass capability needed by the ISS), and the Europeans and Japanese have been told they will not have access to the new VSE program. The decision to stop flying the space shuttle signaled that the United States is no longer interested in the ISS, and that after 2010 other nations largely will be on their own. Potential international partners will think twice before joining the U.S. in future endeavors. NASA plans to buy trips to the ISS on Russian *Soyuz* and *Progress* (cargo) spacecraft, but with relations between the United States and Russia at a low point, Congress has already questioned the arrangement.

The Bush administration's commitment to shut down the shuttle program by 2010 and purchase future trips to ISS has severely limited the nation's capability to continue to fly Americans into space. The currently planned replacement vehicle cannot be ready much before 2015 and, realistically, probably much later. Progress on developing the new "*Constellation*" space vehicle—an Orion crew exploration vehicle riding on a new *Ares I* rocket—has been delayed due

to a number of significant technical design problems. Even if all the problems can be solved with considerably more time and money, the capabilities of the new system fall far short of the shuttle in many ways. For instance, the *Orion* capsule, a larger version of the 1960s *Apollo* capsule, does not allow for extravehicular activity, cannot stay long in orbit, carries no payload up or back, and requires a water landing.

Given budget and manpower shortfalls, NASA is unable to provide firm cost estimates, while tight White House deadlines continue to put pressure on the Ares I and Orion projects. Both are likely to experience substantial schedule slips and growth in costs. The best "advertised" estimate of when the *Constellation* might fly is 2015, though realistically it could be much later. We could be looking at a flight gap as great as eight years or more. And all the while, science and aeronautical research will continue to be held hostage.

It is distressing to observe the current state of the U.S. space program as the nation moves into a new progressive era with the inauguration of President Barack Obama in January 2009.

Despite having brilliantly succeeded in assembling over a million pounds of hardware in the multinational international space station and having endured heartbreaking tragedy and recovery in the space shuttle program, NASA finds itself in an almost impossible situation. The Bush administration's focus on the VSE has resulted in a number of consequences: After 2010, the United States will be dependent on Russia for transport to space and will have to pay for each trip; that, as well as the de-emphasis of science, including research on the ISS, undercuts the investments of our international partners. Additionally, the proposed Constellation system will be over budget, behind schedule, and of limited capability. Finally, the rationale for a total focus on returning to the moon is weak. It has not resulted in a national consensus, nor is there any apparent pressing national concern except, possibly, that China might land on the moon at the end of the decade.

Recommendations

In the short term, NASA's deep space human spaceflight efforts can be rapidly redirected from the moon and Mars to focus on technical issues related to energy and the environment by placing greater emphasis on research on Earth and in low Earth orbit, including enhanced satellite Earth observation systems. At the same time, NASA can plan, with international partners, for a truly visionary cooperative space exploration program beyond Earth orbit.

Energy security and threats to the environment—particularly climate change and its impact on the Earth's ecology, land surfaces, oceans, and people across the globe—will be the most significant challenges faced by humankind in the next 50 years and beyond. National and domestic security, foreign policy, the economy, and social equality will be increasingly dependent on our response to these two challenges. NASA has three great resources to make significant contributions in these areas.

First, NASA has a unique capability to operate in air and space, giving it an extraordinary vantage point for observing the Earth's environment. NASA has played this critical role for the nation since the launch of the first Landsat satellite in the 1970s. Unfortunately, NASA has been reluctant to significantly publicize its efforts, in part because of the political controversy surrounding global warming and climate change. This impediment should be removed both by the growing scientific evidence of global climate change, as well as the openness of the new administration to necessary policy actions.

Second, NASA has unique tools for understanding modeling and managing large-scale processes and projects. Tools such as computer modeling, large-scale computing, aircraft, satellites, and communications are required for this work. A strong partnership between NASA, the National Oceanic and Atmospheric Association (NOAA), which has major responsibilities for weather and climate predictions, the U.S. Geological Survey (USGS) and the National Center for Atmospheric Research (NCAR), supported by the National Science Foundation, will be critical to future U.S. capability in weather forecasting and climate projections. But only NASA has the

scientific, engineering, and technical capability to design and launch satellites that are needed for Earth observations.

Third, because of its unique mission, NASA has developed extensive engineering experience relevant to alternative energy systems such as wind turbines, solar cell arrays, batteries, and fuel cells. It is also the primary federal agency with the experience to improve the fuel efficiency of all types of aircraft. These capabilities have not been in the public eye but, nevertheless, have been essential to the success of NASA missions since its creation immediately after the launch of Sputnik.

Recommendation 1: Restructure the human space initiative and keep the space shuttle flying until 2015.

This is by far the most challenging element of the five-point plan. One approach to restructuring would be to switch the early focus from the moon and Mars to enhanced support of the international space station. A clearly stated rationale for the ISS, such as continued international cooperation on the peaceful uses of space, scientific research in particular, would be important. Extending space shuttle flights through 2015 would reduce reliance on Russia for transportation to the ISS and provide the large up-and-down mass capability needed by all ISS partners.

The Constellation program would be restructured by canceling *Ares I*. *Ares I*, if successful, doesn't offer much of an advantage over other Earth-to-orbit launchers and its development will take too long and use valuable funds. In addition, canceling other lunar surface-related work—including the lunar lander, the space suit, the rover, and other habitat and surface systems work—would focus the NASA workforce on immediate challenges. These activities can be resumed at an appropriate time in the future.

Canceling human-Mars discussions would be a pragmatic statement that recognizes the incredible challenges of a Mars mission. Robotic missions to Mars should be flown exclusively, at least for the next decade, with extensive surface exploration by rovers.

The present Orion program would be restructured to reduce the size of the new spacecraft to a three-member crew, *Apollo*-sized vehicle or an X-38 lifting body vehicle with land-landing capability. The smaller-sized vehicle would be flown on an *Ariane 5* or *Delta IV* launch vehicle, with a planned 2014 or 2015 launch to the ISS. Moving to one of these launch vehicles allows a more rapid deployment by decoupling the new spacecraft from the development of a new launcher such as *Ares I*. Development of the new spacecraft would be accelerated by reducing the crew size and the need for weight efficiency, and taking advantage of previous Apollo and/or X-38 development. This significantly reduces the technical risk in many key areas, such as thermal protection and parachutes. Weight and technical risk can be further reduced by designing the service module for ISS service missions, making it simpler.

Europe and Japan should be invited to participate as Europe participated in the X-38 program. Parts would be provided in return for services (i.e., future launches to ISS). In order to ensure this international participation is meaningful and effective, the recommendations stated in the recent National Research Council report, "Beyond Fortress America," should be implemented. This report provides an excellent assessment of the impact of building walls that compromise our ability to access global science and technology and that adversely affect our ability to compete globally. The report makes recommendations to reform the export control process, ensure scientific and technological competitiveness, and improve the nonimmigrant visa system that regulates entry into the United States of foreign science and engineering students, scholars, and professionals. It calls for immediate action "to stem a serious decline affecting broad areas of the nation's security and economy."

By not investing in a unique *Ares I* Earth-to-orbit human launcher, NASA will be positioned to take full advantage of emerging commercial Earth-to-orbit transportation services should they develop in the 2015-2020 timeframe.

In our restructuring approach, the shift in near-term focus from lunar to ISS would be followed by building a capability for deep space asteroid or comet intercept as a longer-term focus based on an *Ares V* heavy lift vehicle. The *Ares V* heavy lift launch capability is critical to any further deep space exploration. By canceling *Ares I*, it should be possible to focus all of the agency's

launch vehicle development capability on designing the one launcher needed by the nation for future deep space work, and the one launcher not anticipated to be provided by the private sector. All options for providing an *Ares V* heavyweight launch capability will be studied, including liquid boosters, liquid fly-back boosters, and international cooperative options. This should include the evaluation of options such as proposed by the Direct Launcher concept that makes use of most of the existing shuttle hardware, including the two solid rocket boosters and the external fuel tank. The only key modifications would be an *Apollo*-like capsule at the top and an engine at the bottom of the external fuel tank. Although *Ares* also uses shuttle parts, it is essentially an entirely new rocket.

The ability to fly to an asteroid would give the United States a lunar capability should one be needed in the future. A deep space mission, such as a human asteroid or comet intercept, would effectively demonstrate American leadership in space, should that be a concern in the face of a possible Chinese landing on the moon. It might even be argued that an American lunar return would do less to question U.S. space leadership than a more aggressive goal of performing a human asteroid intercept mission.

To advance this and other concepts, a joint NASA-DOD propulsion research program should be initiated, as propulsion is a limiting factor in space exploration. An aggressive program focused on innovative advanced propulsion development has been needed for a long time.

A restructured human spaceflight initiative should be premised on the idea that any future plans by the United States to return women and men to the moon, and someday to Mars, will need to be top national priority. It should involve many U.S. federal agencies, universities, and industries, and be fully international in scope. By restructuring the human spaceflight initiative, resources will be made available to allow NASA to contribute to other vital short- and long-term national priorities.

Recommendation 2: Deliver short-term (within four years) payoffs in energy and the environment, especially in the area of climate change.

This recommendation takes advantage of the unique capabilities and skilled workforce of each NASA center. The efforts of the various centers would be refocused and assigned responsibilities commensurate with their expertise. The short-term payoffs would involve initiatives to fully understand and optimize the aerodynamics, structures, and mechanisms of large-scale wind turbines; to fully understand and optimize high-efficiency, large-scale solar cells and small-scale fuel cell technology applications; to improve aerodynamic and propulsion efficiency of general aviation and commercial aircraft; and develop and evaluate alternative aviation fuels and aircraft power plants.

Initiatives would be implemented to fully employ NASA's ability to monitor, model, and predict long-term climate, utilizing NASA instruments, aircraft, spacecraft, computers, and communications. This effort could include enhanced use of the ISS for monitoring the Earth and expanding the current Earth Observing System (EOS), and would require close coordination with the NOAA, USGS, and the National Center for Atmospheric Research, supported by National Science Foundation.

In addition, robotic exploration would be implemented to compare the Earth to sister planets. This could lead to a better understanding of Earth planetary science.

Breakthroughs in all of these areas, as well as the development of better solar and fuel cells and improved knowledge of the environment and planetology, are essential to future exploration activities.

Recommendation 3: Deliver longer-term payoffs (within four to eight years) for energy and the environment.

As a potential long-term energy solution, an effort would be made to demonstrate—initially on a small scale—wireless power transmission from orbit to the Earth using the shuttle and the ISS. Full implementation of a space-based solar power system requires a larger and less costly launch infrastructure than is currently available. It isn't feasible until launch costs can be reduced.

However, a low Earth orbit demonstration, potentially based on the shuttle or the ISS, would allow us to understand the problems and required efficiencies. This concept has made major strides since its initial inception with the realization that constellations of smaller, more efficient solar collectors in medium Earth orbit can provide the same capability as larger, high orbit satellites. Demonstrating space-based solar power on a small scale would help us better understand what would need to be done to utilize this concept for supplying electrical power needs. Additional small-scale efforts would be initiated to demonstrate other potential technologies for healing the planet that are tied to NASA's ability to monitor, model, and engineer large-scale complex systems

This recommendation would again utilize the unique capabilities of the appropriate NASA centers.

Recommendation 4: Ensure an ongoing and effective robotic space science program.

NASA's ongoing and effective robotic space science program would be expanded, with special emphasis given to university research, and should be based on strong and active international cooperation. Working with the nation's universities and drawing on their knowledge and expertise, NASA should provide support for a large, strong, and effective graduate student program. The National Defense Education Act, originally instituted in 1958, served the nation well in the past. The Act's intent was to ensure the nation's security by developing the mental resources and technical skills of its young men and women. Key features of the legislation included a student loan program to colleges and universities to increase the flow of students into science, mathematics, and foreign language careers; a "National Defense Fellowship" for graduate study toward a college teaching career; and a wide array of programs to enhance pre-college teacher training and public understanding of science and technology. Combined with an active and meaningful partnership between NASA and the nation's universities, it could help to address the potential shortage of young U.S. scientists and engineers.

Recommendation 5: Implement a reinvigorated and effective aeronautical research program, with particular attention to low-carbon fuels and efficiency, to help ensure the future well-being of the nation's aviation industry.

Aeronautical capabilities are important to the U.S. economy, but the aeronautics segment is becoming less competitive. The U.S. share of the world aerospace markets has declined significantly since the mid-1980s. In the past, the NASA aeronautics research and technology program has produced significant advancements in aeronautical design. The low-drag cowl for radial engines and the "Coke-bottle" to reduce transonic drag rise are excellent examples of the benefits gained from NASA's aeronautical research program.

More recent aeronautics advancements such as multi-axis thrust vectoring exhaust nozzles integrated with aircraft flight-control systems; fly-by-wire flight control technologies; high-strength, high-stiffness fiber composite structures; and tilt-wing rotorcraft technology have been achieved in partnership with NASA's research and technology programs. Modern aircraft are complex "systems of systems," and advances in one discipline, such as aerodynamics, may require an advance in another discipline, such as structures, before they can be applied in a new aircraft design. A NASA fundamental aeronautical research and technology program, not tied to specific development projects, would be an essential element of the reinvigorated aeronautics initiative and would provide the foundation for such future advancements.

Government aeronautical test facilities are another area of concern. Many facilities have been or are being closed down. U.S. aircraft companies are going overseas to perform wind tunnel testing of new U.S. designs. A reinvigorated and more effective aeronautical research program must include a review of the present status of the nation's aeronautical test facilities and the identification of the upgrades and new construction needed to ensure the support of the revitalized aeronautical research program.

Conclusion

Since its inception in 1958, NASA has compiled a record of outstanding achievements, both in space and in aeronautics. It has taken men to the moon and returned them safely to Earth. It has advanced our understanding of our planet and the universe, and its technological advancements have benefited life on Earth for all mankind. As Dr. Michael DeBakey has said, "hospital operating rooms and modern health monitoring and care would not be what it is today were it not for NASA technology."

NASA has set the standard for international cooperation and developed the most successful manned space vehicle ever built, the space shuttle. And yet, as it successfully completes the largest international cooperative technological project in history, the international space station, NASA's Vision for Space Exploration leaves the nation with no capability to continue to fly humans in space for a significant period of time. The new vision basically focuses the agency on a single mission, moving NASA away from a balanced set of activities—to the detriment of science, engineering, research and technology, and aeronautics—that have contributed so much to the nation's leadership in space and aeronautics.

The proposed five-point plan takes the agency in a direction that will significantly contribute to the future of the United States and the American people, indeed to all humankind, in two vital areas: energy and the environment, especially climate change. Under the plan, NASA will continue to fly humans in space, complete the international space station, meet its commitments to our international partners, and re-establish a balanced set of activities featuring science, engineering, aeronautics, research, and technology. It will build a foundation for a human exploration program that involves other agencies, the nation's universities, and is based on international cooperation.

A key stated objective of all NASA research and technology programs will be to excite a new generation of scientists and engineers and rebuild scientific and technical expertise within NASA and across the nation—a critical need highlighted in the National Academies report, "Rising Above the Gathering Storm." This 2005 report, prepared in response to a request from Congress,

identified and recommended strategies for implementing ten actions that could enhance science and technology enterprise and allow the United States to successfully compete, prosper, and be secure in the global community in the twenty-first century. NASA's research center structure would be re-established with this objective in mind, creating a strong link to the nation's universities. As a part of this restructuring, greater authority and responsibility would be returned to the center directors. The full cost accounting constraints that require projects to pay for personnel, and for all personnel to be paid by projects, would be removed. Personnel would be funded from a common pool as they were during NASA's entire history, prior to recent times. Full cost accounting requires each engineer or scientist to be supported by a program and does not allow for an organization of engineers and scientists devoted to research and development, a constraint that all but eliminates the agency's ability to build and retain its technical and scientific expertise.

A new and unique window of opportunity is available to re-establish NASA as an exciting and innovative organization that is both immediately relevant and can contribute solutions to the nation's most pressing needs while continuing our scientific quest and our human desire to explore the frontiers. We offer an approach to resetting priorities for the U.S. space program and restructuring NASA that we believe would accomplish these goals. And we believe that the benefits of this approach to the nation are great. Whether or not our proposal is heeded, the status quo is not an acceptable option.