

**Statement of Steven W. Squyres
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Mr. Chairman and Members of the Committee, thank you for the opportunity to appear today. My name is Steven W. Squyres, and my title is Goldwin Smith Professor of Astronomy at Cornell University. I have participated for the past thirty years in a number of NASA solar system exploration missions. Recently I chaired the planetary decadal survey for the National Research Council, and I am currently the Chairman of the NASA Advisory Council. The views that I express today are my own, and do not represent the opinions of the National Research Council, the NASA Advisory Council, or any other organization.

The subject of today's hearing is the NASA Authorization Act of 2013. The draft legislation is long and detailed, and I will not attempt to address all of it in my testimony. I will focus instead on aspects that I find to be particularly worthy of comment.

Three themes run through my testimony today:

- NASA needs a clear and compelling long-term goal. That goal should be to send human explorers to Mars.
- NASA is being asked to do too much with too little. Unless program content can be matched to budget, the result will be wasted effort and delay.
- Our nation's civil space program will be best served by having high-level policy set by the Administration and Congress, and implementation details recommended by NASA engineers, scientists, and managers.

Human Space Flight

I recently participated in a hearing before this committee entitled "Next Steps in Human Exploration to Mars and Beyond". An underlying assumption of that hearing was that a crucial future goal for NASA should be to send human explorers to the surface of Mars. In my testimony then I strongly supported that goal, and I reiterate that support today.

Alone among the planets, Mars is enough like Earth that we can imagine life once taking hold there. A vast and growing body of scientific knowledge shows that the martian

surface once possessed many of the essential ingredients required for life. If by exploring Mars we could show that life emerged there – and therefore that it emerged twice in just this one solar system – it would take no great leap of faith, logic, or anything else to conclude that life may be commonplace throughout the cosmos.

One could ask whether it is necessary to send humans to Mars to answer this question. Despite having devoted my career to exploring the solar system with robots, I am a strong advocate of human exploration, particularly at Mars. Humans have an extraordinary ability to function in complex environments, to improvise, and to respond quickly to new discoveries. Robots, in contrast, do best when the environment is simple and well understood, and when the scientific tasks are well defined in advance. Because the capabilities of humans most surpass those of robots in complex environments, the exploration value that humans add is in proportion to the complexity of the environment to be explored. And there is no planetary environment where humans can operate in the foreseeable future that is more complex than the martian surface.

We also must not underestimate the inspirational value of human explorers on Mars. I can tell you from personal experience that NASA's long-lived Spirit and Opportunity Mars rovers were designed and built by people like me who grew up watching the Apollo lunar landings on television, and dreaming of sending spaceships to Mars one day. Sending humans to Mars would surely provide an even more compelling inspirational spark for the next generation of scientists, engineers, and explorers.

Sending human explorers to Mars to learn whether life ever emerged there is a goal worthy of a great national space agency. In my view, it is appropriate to make this goal NASA's top priority.

To make progress toward this goal, the draft Authorization Act wisely calls for NASA to develop “a Mars Human Exploration Roadmap defining the capabilities and technologies necessary to extend human presence to the surface of Mars”. But then, with almost no technical justification, the draft legislation also dictates what some of the key elements of that roadmap should or should not be. Specifically, it directs NASA to “establish a program to develop a sustained human presence on the Moon”, and forbids NASA to “fund the development of an asteroid retrieval mission to send a robotic spacecraft to a near-Earth asteroid for rendezvous, retrieval, and redirection of that asteroid to lunar orbit for exploration by astronauts.”

I believe that it would be unwise for Congress either to prescribe or proscribe any key milestones in NASA's Mars exploration roadmap at this time. To do so would put the cart before the horse. Personally, I agree with the draft Authorization Act's position on the Asteroid Retrieval Mission, and I disagree with its position on a sustained lunar presence. But my personal views are not the point. In the 1960s, the government set the high-level goal of sending humans to the Moon, and then left it to the engineers, scientists, and managers of NASA to find the right program architecture to achieve this goal. I believe that a similar approach should be taken to the achieving the goal of getting humans to Mars.

The key early elements of the architecture that will be used to get to Mars have been agreed upon and are in development. The Space Launch System will provide an initial heavy lift capability, the Orion crew capsule will provide short-duration crew support, and the early flights will be to lunar orbit. Other pieces of the puzzle – new technologies and new vehicles – will be needed later. But these provide a start.

Beyond lunar orbit, milestones that could be considered include an asteroid that has been redirected to lunar orbit, the lunar surface, a near-Earth asteroid, Mars orbit, and the moons of Mars. I urge that milestones not be dictated, either by the Administration or the Congress, without allowing NASA to develop a technically sound Mars roadmap first. The objective of this roadmap should be to achieve the goal of human exploration of Mars as quickly and efficiently as possible. Once a viable roadmap has been generated, the additional technologies, vehicles, and milestones that are needed to make it a reality will become clear.

Moving on to funding levels in the draft Authorization Act, I find cause for serious concern regarding even the most near-term elements of NASA's human exploration program. Nowhere is the mismatch between NASA's aspirations and its budget manifested more clearly.

I have previously testified before this committee regarding the implications of NASA's budget for the flight rate of SLS and Orion. The current cost-constrained development schedule for SLS and Orion calls for:

- In 2014, an orbital test flight of an Orion capsule with no crew, to be launched on a Delta 4 Heavy.
- In 2017, a lunar flyby test flight of an Orion capsule with no crew, to be launched on a 70-metric ton SLS.
- In 2021, eight years from now, the first flight of a crew in an Orion capsule, again launched on a 70-metric ton SLS, on a mission to orbit the Moon.

Subsequent missions would occur on a "pay-as-you-go" basis, with a launch roughly every two years.

I believe that the low flight rate projected for SLS and Orion is a serious problem. No human-rated launch system in NASA's history has flown so infrequently. With such a low launch rate it will not just be difficult to maintain program momentum; it will be difficult to keep flight teams sharp and mission-ready.

So the problem with dictating future milestones now is not just that it puts the cart before the horse. In a situation where funding for even the nearest-term elements of human space exploration is inadequate, dictating a milestone like a sustained presence on the surface of the Moon would also amount to giving NASA an unfunded mandate.

Unfunded mandates are the bane of any government agency. They can be particularly crippling for an agency like NASA that is tasked with attempting things that have never been done before, with the uncertainties regarding schedule and budget that invariably result. If NASA is directed to do something it is not funded to do, I predict that the result will be wasted effort and a delay in achieving the ultimate goal of humans on Mars.

Space Science

Space Science has been one of NASA's major success stories for many years. From the Hubble Space Telescope to the Kepler exoplanet discovery mission to the Mars rover Curiosity, Space Science missions are addressing some of the most significant scientific questions of our day, and are captivating the American public in the process.

Priorities across the full sweep of Space Science have been recommended by the National Research Council's Decadal Surveys. These surveys are generated with broad input from the U.S. and international science communities, and reflect strong consensus views regarding science objectives and mission goals. I am pleased, therefore, that the draft Authorization Act places particular emphasis on assuring that NASA's Space Science program follows decadal priorities.

Unfortunately, tight budgets and mission cost overruns have put NASA's Space Science program under pressure. The Administration and the Congress clearly have different priorities for Space Science, and those differences are brought into sharp focus by this draft Authorization Act.

Recent Administration budget requests have funded most Space Science disciplines adequately, but have included cuts to planetary exploration that were so deep as to seem punitive. The draft Authorization Act, in contrast, restores funding for planetary exploration but introduces alarmingly deep cuts to Earth science.

In difficult budget times, some belt-tightening in Space Science is inevitable. But I feel it is important that cuts be driven by science priorities as outlined in the Decadal Surveys, and that they be distributed sensibly across disciplines. I urge this committee to strive for balance in the Space Science portfolio, rather than singling out Earth science, or any other discipline, for disproportionate cuts.

Aeronautics

In previous Congressional testimony, I have said that NASA's aeronautics program is one of the Agency's shining jewels. I stand by that characterization. If you ask what things NASA does that most directly benefit taxpayers in their daily lives, it's hard to find anything better than the aeronautics program.

I am pleased, therefore, that the draft Authorization Act continues funding for Aeronautics at approximately its current level. Most of the draft language calls for plans and reports to be provided Congress regarding Aeronautics activities; these will serve to keep the Congress well informed in these areas. I see no significant problems regarding the Aeronautics sections of the draft Authorization Act.

Space Technology

Technology development enables NASA's future missions, and decades of experience have shown that adequate upfront investment in technology is a key part of controlling mission costs. Effective management of NASA's Space Technology program is therefore essential.

The draft Authorization Act would reorganize the Space Technology program by moving much of the responsibility for exploration-related technology development to the Human Exploration and Operations Mission Directorate. Some aspects of this proposed reorganization concern me. There is indeed value in having some funding for development of specific technologies reside within NASA's mission directorates, so that the development can be aligned with that directorate's mission goals. The problem is that when budgets are tight it is tempting for mission directorates to use technology funds to solve today's problems rather than enabling tomorrow's missions. So I tend to favor a more distributed approach in which only technology funding for specific near- and medium-term needs of a mission directorate reside within that directorate. I feel that longer-term and more broadly applicable exploration technology funding is better maintained in a separate technology organization, helping protect it from being used to solve immediate mission problems.

I will also note that in order to find and fund the best ideas, it is important for a significant fraction of NASA's Space Technology program to be openly competed.

Education and Outreach

The President's FY 2014 budget request proposed a major restructuring of science, technology, engineering, and math (STEM) education and public outreach at a number of federal agencies. For NASA, this restructuring would eliminate most of the Agency's STEM education efforts, consolidating them under other government organizations that have little or no experience with space flight.

I believe that the restructuring proposed by the Administration is deeply misguided. NASA's space missions are unique within the federal government, both in their technical audacity and in their capacity to educate and inspire. The education and outreach components of NASA's missions have been enormously successful, in large part because they are managed and run by people who have a deep knowledge of the subject matter and a passion for sharing it.

I believe that dismantling NASA's education and outreach efforts would deal a serious blow to our nation's scientific and technical literacy. So I am very pleased that the draft Authorization Act states that NASA "may not implement any proposed STEM education and outreach-related changes proposed in the budget for fiscal year 2014".

Agency Leadership and Management

The draft Authorization Act includes provisions regarding leadership and oversight of NASA. Among these is language calling for establishment of a NASA Advisory Council. I note that both the membership and the responsibilities of this group would be dramatically different from those of the body that is now called the NASA Advisory Council, which I currently chair and which reports only to the NASA Administrator.

I support the formation of a body that is jointly appointed by the Administration and the Congress, and that reports to both regarding NASA. In the absence of such a body, there has been an unfortunate tendency for NASA's implementation of national space policy to be overseen in what I view to be excessive detail, particularly by OMB. I have argued above that the government should set high-level policy (like the goal of sending humans to Mars), but that many of the implementation details are better devised and recommended by experienced NASA engineers, scientists, and managers. A high-level advisory body with deep technical and management experience could help provide the Administration and the Congress with assurances that the right recommendations are being made by the Agency, and could suggest corrective actions when necessary.

The devil will be in the details in the establishment of such a group. I note that the draft language calls for eight members to be appointed by Congress but only three by the Administration, an imbalance that could be problematic. I also note that careful coordination will be required to assure that the appropriate range of expertise is represented on the group. But I support the concept strongly.

Overcommitment of NASA: A Possible Long-Range Solution

I believe that the mismatch between NASA's aspirations and its budget is the most serious problem facing the Agency. Unless a solution is found, some very hard choices may have to be made soon. Specifically, a choice is looming regarding whether the focus of human space flight should be ISS utilization or moving beyond low Earth orbit. At projected budget levels, I fear that NASA will not be able to do both of these safely and well.

As I noted the last time I appeared before this committee, part of the solution may be international partnerships. If no major funding increase for NASA is forthcoming, then I believe that the Agency should aggressively seek out international partners for human exploration beyond low Earth orbit. As one example, an international partner might

provide a habitation module that would allow long-duration missions into deep space. If capable partners who are willing to shoulder a substantial fraction of the cost of deep space exploration can be found, then it may be possible for NASA to maintain something like its current portfolio of activities. Otherwise, I fear that a painful reduction in program content lies ahead.

Despite the challenges that it faces, NASA is one of our nation's greatest assets, and is a source of pride for all Americans. An Authorization Act that enunciates a clear and compelling long-term goal for the agency, that matches program content to budget, and that lets NASA formulate the implementation details of national civil space policy will allow it to remain so.