Statement of Steven W. Squyres
Goldwin Smith Professor of Astronomy
Cornell University

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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.

Moving Beyond Low Earth Orbit

The topic of today's hearing is implementation of the NASA Authorization Act of 2010. In my testimony, I will focus primarily on the elements of that act dealing with extension of human exploration beyond low Earth orbit, with particular emphasis on the eventual exploration of Mars.

A central focus of the 2010 Authorization Act was the development of two crucial elements of a deep space exploration capability: The Space Launch System (SLS), and the Orion multi purpose crew vehicle. In my opinion, NASA has made good progress in both of these programs.

Crucial recent events in the SLS development have included completion of the vehicle's System Requirements and System Definition reviews, as well as successful test firings of the J-2X cryogenic engine for the vehicle's upper stage. In the Orion program, several major milestones in the test program have been passed, including water drop tests, a test of the launch pad abort system, and a series of parachute tests. Importantly, the first Orion command module has been delivered to Kennedy Space Center.

So NASA's development of both SLS and Orion, as called for in the 2010 Authorization Act, is well underway.

What will these vehicles be used for?

In a speech at Kennedy Space Center on April 15, 2010, President Obama outlined his Administration's goals for human exploration of space. He called for sending humans to an asteroid by 2025, to Mars orbit by the mid 2030s, and to the surface of Mars

subsequently. These are grand goals, and they are broadly consistent with the goals expressed by the 2010 Authorization Act.

Asteroids are important targets for exploration. Scientifically, asteroids contain clues regarding the formation and earliest evolution of the solar system. Practically, they present both an opportunity and a threat. Mining of asteroids could yield raw materials of enormous value for use in space, simply because they need not be lifted from the Earth's gravity well. And we know that asteroids have impacted the Earth in the past with devastating effects, and will do so again in the future unless we develop an understanding of these bodies sufficient to prevent such an event.

As for Mars, I feel that sending humans to that planet to with the objective of learning whether life ever took hold there is a goal worthy of a great national space agency. I agree with the 2010 Authorization Act that "A long term objective for human exploration of space should be the eventual international exploration of Mars." In fact, in my view, it should be *the* long term objective for human exploration of space, whether carried out internationally or by NASA alone.

So I disagree with critics who contend that NASA does not have clear goals for human exploration beyond low Earth orbit. In fact, the goals are quite clear, and they have been articulated without ambiguity. Moreover, two of the key elements for achieving those goals – SLS and Orion – are in development and proceeding well.

But I see two significant problems.

One is that the "pay-as-you-go" approach called for in the 2010 Authorization Act can result in disturbingly slow progress if funding levels are inadequate. 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, nine years from now, the first flight of a crew in an Orion capsule, again launched on a 70-metric ton SLS, on some mission to be determined.

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 currently projected for SLS and Orion is a cause for concern. No human-rated launch system in NASA's history has flown so infrequently. With such a low launch rate it would not just be difficult to maintain program momentum; it would be difficult to keep flight teams sharp and mission-ready.

A more serious concern is that the SLS/Orion combination alone is insufficient to carry out missions to any important destinations beyond low Earth orbit. The Orion capsule can support a crew of four for three weeks, which is far too short a time to conduct a mission to an asteroid. An asteroid mission therefore requires development of another major piece of hardware, capable of providing crew support in deep space for many months. There is no funding in NASA's budget to develop this hardware.

Three weeks is enough time for a mission to the surface of the Moon, which like an asteroid mission could be a reasonable stepping-stone to Mars. But such a mission would require a lunar lander, which again is not in NASA's budget.

So if we truly intend to have a program of human exploration to some destination beyond low Earth orbit, there is a piece of the puzzle missing. SLS and Orion will be highly capable vehicles, and their development is progressing well. But they are only part of the picture. Without some means to develop or acquire the missing piece – either a deep-space habitation module or a lunar lander – a decade from now NASA will be unable to do much more in deep space than duplicate the success of Apollo 8's historic mission to orbit the Moon, more than half a century later.

The Ultimate Goal of Mars

As I noted above, I believe that the ultimate goal of NASA's human exploration program should be Mars. As was done in the days prior to Apollo, robotic missions can and should should serve as precursors to human exploration. At Mars, the goal of these missions should be more than to collect engineering data necessary to get humans to the planet and safely back to Earth. It should also, critically, be to lay the scientific foundation on which human exploration will be built. If human exploration of Mars is to be for more than "flags and footprints", the scientific case for this exploration must be compelling and clear.

In the recent planetary decadal survey that I chaired, the highest priority "flagship" mission identified by the National Research Council was a Mars rover mission that would initiate a campaign to return samples from the surface of Mars. This mission would be responsible for characterizing a landing site that has been selected for high science potential, and for collecting, documenting, and packaging samples for return to Earth. The Mars science community, in their inputs to the decadal survey, was emphatic in their view that a sample return mission is the logical next step in Mars exploration. Mars science has reached a level of sophistication that fundamental advances in addressing the most important questions will only come from analysis of returned samples. This mission would also explore a new site and significantly advance our understanding of the geologic history and evolution of Mars, even before the cached samples are returned to Earth. A crucial aspect of the Mars sample return campaign as originally envisioned was that it would be carried out in partnership with the European Space Agency (ESA), reducing the costs to NASA.

Unfortunately, NASA has been unable to follow this recommendation from the NRC. The reason for this is simple: deep proposed cuts to NASA's F.Y. 2013 budget for Mars exploration prevent it. And in the face of these cuts, the hoped-for partnership with ESA has not come to fruition.

If no commitment to a Mars sample return mission is made in response to the decadal survey recommendations, the result will be highly detrimental to the future of U.S. planetary science. More pragmatically, I fear that an inability to enter into a mutually beneficial partnership with a willing, eager, and highly capable agency like ESA could jeopardize future international partnerships as well. And most importantly, the scientific investigation of Mars that should provide the underpinning for future human exploration will be lost.

Possible Paths Forward

As I look at NASA's response to the Authorization Act of 2010, I cannot escape the conclusion that the agency is being asked to do too much with too little. The act provides the agency with a clear set of goals and priorities. The Administration has provided another set of goals and priorities. These two sets of guidance are not dramatically dissimilar, but taken together they call for more than the agency can do with the budget it has. This mismatch between objectives and resources is the reason that a crucial piece is missing from our development of a robust capability for human exploration of deep space. It is also the reason we have seen deep cuts to a program to explore the very solar system body to which we hope humans will one day be sent.

In such a situation, I can see four possible paths forward. One, of course, is to keep trying to do everything called for with an inadequate budget, running the risk of lengthy delays and a job poorly done. In an undertaking as difficult as human exploration of deep space, that is not a good approach. I urge the Congress to avoid this path.

A second is to make painful choices, eliminating some of what NASA does to preserve full and adequate funding for other things it aspires to do. That could be done, but it would require reaching a national consensus on priorities for space exploration that does not now exist.

A third is to increase the agency's budget, making all the things it being asked to do possible. This path is desirable, but is perhaps unrealistic in a constrained budget environment.

A fourth path is to broaden NASA's capabilities by forging strong international partnerships. This approach has worked well in the past. The Cassini-Huygens mission to Saturn is an example on the scale of a planetary flagship mission, and the International Space Station is an example on the scale of a major agency initiative.

Right now there is no real plan for international participation in NASA's future human exploration beyond low Earth orbit, and the hoped-for collaboration with ESA on future

Mars missions has been set aside, at least temporarily. But international collaboration is the path that I believe may hold the greatest potential for bridging the gap between what NASA is being asked to do and what its budget allows it to do.