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Mr. Chairman and Members of the Subcommittee, 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.

The Planetary Decadal Survey

The NRC's decadal survey report was requested by NASA and the National Science Foundation to review and assess the current status of planetary science and to develop a comprehensive science and mission strategy. The committee that was established to write the report broadly canvassed the planetary science community to determine the current state of knowledge and to identify the most important scientific questions to be addressed during the period 2013-2022. The report presented, to the greatest extent possible, the consensus view of the planetary science community.

The principal support for research related to solar system bodies in the United States comes from the Planetary Science Division (PSD) of NASA's Science Mission Directorate. The annual budget of PSD is currently approximately \$1.3 billion. The bulk of this is spent on the development, construction, launch and operation of spacecraft. Two types of spacecraft missions are conducted: large "Flagship" missions strategically directed by the PSD, and smaller Discovery and New Frontiers missions proposed and led by principal investigators. In my testimony today, I will focus, as requested, on the issue of Flagship missions.

Flagship Missions in a Balanced Program

Because my testimony today concerns Flagship missions, I will particularly stress the issue of programmatic balance. The challenge faced by NASA is to assemble a portfolio of missions that achieves a regular tempo of solar system exploration and a level of investigation appropriate for each target object. A program consisting of only Flagship missions once per decade or even less frequently could result in long stretches of relatively little new data being generated, leading to a stagnant community. However, a portfolio of only smaller missions would be incapable of addressing important scientific

challenges like in-depth exploration of the outer planets or returning samples from Mars. A key finding of the decadal survey was that “NASA’s suite of planetary missions for the decade 2013-2022 should consist of a balanced mix of Discovery, New Frontiers, *and Flagship missions* (emphasis added), enabling both a steady stream of new discoveries and the capability to address larger challenges like sample return missions and outer planet exploration.” The program recommended by the NRC was designed to achieve such a balance.

I should also remark on the NRC’s recommended decision rules, which dealt with how to reshape the program if necessary in the face of declining budgets. The decadal report did not state that Flagship missions have lower priority than other smaller missions. It stated that an appropriate response to declining budgets is to *delay or descope* Flagship missions – a very different matter from eliminating them.

Flagship Mission Priorities

Based on the broad inputs from the planetary science community and the prioritization criteria described above, the decadal survey identified and prioritized a number of candidate Flagship missions.

The highest priority Flagship mission identified by the NRC is a Mars rover mission that would be the first of three missions in a campaign to return samples from the surface of Mars. It 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 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 important questions above 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 entire Mars sample return campaign is that it would be carried out in partnership with the European Space Agency, reducing the costs to NASA. I will return to this point below.

The second highest priority Flagship mission identified by the NRC is a mission to characterize Jupiter’s moon Europa. Europa is likely to have a deep ocean of liquid water beneath its icy crust, making it an object of enormous interest as a possible abode for life. The mission would put a spacecraft in orbit around Europa, investigating its probable ocean and interior, its ice shell, its chemistry and composition, and the geology of prospective landing sites.

The third highest priority Flagship mission is an orbiter and probe mission to the ice giant planet Uranus. Galileo and Cassini have performed spectacular in-depth investigations of the Jupiter and Saturn systems, respectively. The Kepler mission has shown that many exoplanets are ice-giant sized. Exploration of a planet like Uranus is therefore the obvious and important next step in the exploration of the giant planets. This mission

would deploy an atmospheric probe into Uranus and then enter orbit, making measurements of the planet's atmosphere, interior, magnetic field, and rings, as well as multiple flybys of the larger uranian satellites.

The Problem

The NRC's decadal recommendations to NASA covered many topics. These included recommended funding levels and content for the planetary research and analysis program and technology development program. They also included specific recommendations for the structure and content of the small Discovery and medium-sized New Frontiers mission lines. I'm pleased to report that in all of these areas, the Agency's response has been to follow the NRC recommendations closely.

Unfortunately, the one area to date where NASA has not followed the NRC's recommendations has been implementation of Flagship missions. As outlined above, Flagship missions are vital to the health of planetary science. And as stressed in the NRC decadal report, Flagship missions are an essential part of a balanced program of planetary exploration. The lack of progress in implementing the recommended approach to Flagship missions is cause for serious concern.

An obvious issue regarding Flagships is their cost. Because the costs of Flagship missions are high, even proportionally modest cost overruns can have serious consequences for the rest of the program. This is the reason that the decadal report placed strong emphasis on independent and conservative cost estimation processes. But even in the current cost-constrained environment the lack of progress in implementing a Flagship mission is surprising.

The Solution

In my view, the publicly-available budget guidelines that have been provided to NASA by the Office of Management and Budget are sufficient to allow the Agency to carry out the Mars sample collection and caching mission recommended as the highest priority by the NRC. The key to achieving this in an affordable way is partnership with the European Space Agency.

As the spectacularly successful Cassini/Huygens mission to Saturn has Titan shown, international partnerships can be enabling for Flagship missions. The NRC report concluded that partnership with ESA is essential for the Mars sample caching mission, and for the Mars program overall. ESA can bring substantial capabilities and resources to a partnership, lessening both the risk and the financial burden to NASA. To date, however, the Administration has not committed to this partnership.

A potential objection to the proposed mission is that it would be the first in a series of three missions required to return the samples to Earth, each involving significant costs. This concern is offset by three factors. First, the first mission in the campaign would do significant new science on its own, partially providing an immediate justification for its

costs. Second, the campaign has been intentionally designed so that the three missions can be spread out in time, substantially if necessary, to spread the costs over an acceptable period. Third, partnership with ESA throughout the entire campaign will substantially lower the total costs to NASA.

Important steps have already been taken to reduce both cost and cost risk. NASA's current concept for the Mars sample caching mission is substantially descope from the original one, in line with the decadal recommendation to descope Flagship missions in the face of declining budgets. In addition, the current concept makes extensive use of existing hardware designs, reducing the risk of unexpected cost growth. Despite this important progress, however, no commitment to the mission has been made.

Summary

If no commitment to a Flagship 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 would jeopardize future international partnerships as well.

I would also like to stress a critical point: The ability to carry out the most challenging tasks in deep space exploration – tasks like landing and roving on Mars – is one of our nation's scientific and technical crown jewels. If we give up that capability by abandoning planetary Flagship missions, then we do a disservice not just to ourselves, but also to future generations of American scientists, engineers, and explorers. In my view, it is essential that NASA maintain this unique capability. The resources to do it within a balanced program are available. What is needed is a willingness to commit those resources to this essential task.

So my message to the Subcommittee today is simple: In order to achieve a balanced program of planetary exploration, and to maintain American leadership in this field, NASA must be permitted to use its available resources to implement the Flagship mission program recommended by the NRC's decadal survey.