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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 am the scientific Principal Investigator for NASA's Mars Exploration Rover project, and I have participated for the past thirty years in a number of other NASA solar system exploration missions.

I welcome the opportunity to talk to you today about NASA's Space Science budget for Fiscal Year 2009. My main impression of the President's FY'09 budget request for Space Science is that it is a valiant attempt to do a lot with a little. The budget contains some very good news, calling for the initiation of several missions that have been high-priority goals of the space science community for many years. These include a Solar Probe mission and a joint NASA-DOE Dark Energy mission, both slated to launch in the middle of the next decade. Both of these missions are consistent with the recommendations of the relevant Decadal Surveys of the National Research Council. I will leave it to others appearing before this subcommittee today to discuss the scientific importance of these missions in greater detail than I can, but I applaud their inclusion in the budget.

There is also good news for study of the Earth, where the President's budget request opens up a funding wedge that will accelerate the recommended flight missions of the Earth Science Decadal Survey. Again, others can comment better than I on the merits of these missions. But speaking as a planetary scientist who has to live on this planet, I welcome the idea of NASA increasing the share of its resources that is devoted to study of the Earth's environment.

In solar system exploration, my own area of expertise, there is both good news and some cause for concern.

The first piece of good news is that the budget includes a healthy increase in funding for Research and Analysis. The R&A program is where the nation reaps the benefits of the space missions that NASA flies; it turns data into scientific knowledge. The R&A program is where many new concepts for planetary missions are born, and where students learn how to do science. Increased R&A funding will mean increased award rates for

research grants, larger grant sizes, and a more productive planetary science community. So this is a very welcome development.

Also among the good news is that there is significant new activity in the long-neglected area of lunar science. NASA recently selected the GRAIL Discovery mission, which will use twin spacecraft to orbit the Moon and map its gravity field in unprecedented detail, addressing long-standing questions about the Moon's internal structure and evolution. In addition, the budget provides funds for three new robotic missions to the Moon to be launched by 2014. These include an orbiting spacecraft called the Lunar Atmosphere and Dust Environment Explorer (LADEE), and two small landers that will touch down near the north and south lunar poles.

This renewed emphasis on lunar science is consistent with NASA's focus on the Moon as the near-term target of the Vision for Space Exploration. Many opinions have been expressed regarding NASA's planned return to the Moon. My personal view is that the Moon is the logical place to go next with humans, because it is the best place to demonstrate the new technologies and vehicles that will be needed to carry astronauts to more exciting and distant destinations like Mars and asteroids. And while I hope that NASA will not get bogged down in extended program of human exploration of the Moon while more appealing targets beckon, one can only welcome new low-cost missions that address science that is directly related to the Agency's central focus.

The budget also calls for the development of an Outer Planets Flagship mission for launch in 2016 or 2017. This mission would be sent to the Jupiter system, to Saturn's moon Titan, or to Jupiter's moon Europa. Any one of these missions would have enormous scientific potential.

The Jupiter system is like a complete solar system in miniature. Jupiter itself is the best example of a giant planet in our solar system, and may be representative of a class of planets that are common throughout the Universe. Its four large moons formed together and yet show enormous diversity, making them a natural laboratory for studying the processes that shape planetary bodies. At Saturn, the Cassini/Huygens mission has revealed Titan to be a complex and fascinating world, with a dense hydrocarbon-rich atmosphere and lakes of liquid methane and ethane on its surface. The chemistry that takes place in Titan's atmosphere may be closely related to some of the chemical reactions that preceded the development of life on Earth. And at Europa, observations from the Voyager and Galileo spacecraft have provided evidence that a deep ocean of liquid water may exist beneath the satellite's icy crust. Europa's ocean, if shown conclusively to exist, may be the best place in the solar system to search for extraterrestrial life.

The Outer Planets Flagship mission is directly responsive to the most recent NRC Decadal Survey for Solar System Exploration. This survey placed high priority on a Europa Geophysical Explorer mission that would scrutinize several of Jupiter's moons before embarking on detailed exploration of Europa.

My excitement over inclusion of an Outer Planets Flagship mission in the President's budget is tempered somewhat by cost concerns. All of the candidate missions being studied are very technically challenging, and all of them will require a substantial up-front investment in key technologies. Given the projected launch dates, there is enough time to prepare for these missions, and I am heartened to see the technology investment beginning now. But NASA's total projected budget for the Outer Planets Flagship mission is unlikely to be adequate for a mission of the complexity demanded by the science goals. To their credit, NASA is clearly aware of this, and the Agency has emphasized the need for a capable foreign partner to make a major contribution to the mission. Foreign partnerships for large outer planets missions can be forged – the Cassini/Huygens partnership between NASA and the European Space Agency has been a spectacularly successful example. But international cooperation can be difficult to bring about and manage, and careful planning with a committed partner will be required for this critically important mission to be a success.

I believe that the area of greatest concern within the Solar System Exploration budget is the Mars Exploration Program.

In presentations to the science community, NASA has described an exciting future program of Mars exploration. This program would continue the ongoing operations of several highly successful spacecraft at Mars, including the Mars Odyssey orbiter, the Mars Exploration Rovers Spirit and Opportunity, and the Mars Reconnaissance Orbiter. It would operate the Phoenix lander that will touch down near the north pole of Mars in May of this year. It would launch the highly capable Mars Science Laboratory mission in 2009 to explore for long distances over the martian surface and study the planet's former suitability for life.

This program also would continue an exciting program of Mars exploration into the second decade of this century. In 2013, an orbiter mission would be launched to study the dynamics and evolution of the upper atmosphere of Mars. In 2016 another major science mission would be launched, either into orbit or back to the martian surface. And then, in 2018 and 2020, the orbital and surface elements of the long-awaited Mars Sample Return mission would be launched.

This program of future Mars exploration would build on the momentum of some of NASA's greatest successes of the past decade. It would be balanced in its scientific content. And by including a sample return mission it would directly address what has been one of the highest priorities in Mars exploration for many years. It is my impression that this program has the strong support of the Mars science community.

Where I see cause for concern is that the President's FY'09 budget request does not appear to contain adequate funds to carry out this program. I base this statement not just on my own intuition, but on a Mars program architecture study in which I participated recently that was chartered by NASA to respond to a request from the Office of Management and Budget. The study was carried out by nineteen senior engineers,

scientists, and cost analysts. The conclusions of the study were reported recently to NASA's Planetary Science Subcommittee, and I will relate them briefly here.

The budget for Mars Exploration in FY'08 was about \$625 million, and last year's annual budget plan going forward from FY'09 to FY'12 was roughly constant at that level. In contrast, the current President's budget request cuts Mars exploration to less than \$390 million in FY'09, and averages only about \$350 million a year for the five years going forward. In the Science Mission Directorate's planning estimates, Mars program funding does not start to ramp up again until FY'17, and does not return to current levels until FY'19.

The FY'09 budget request includes all of the money necessary to fly exciting science missions in 2013 and 2016. It also contains \$68 million in technology development funding for Mars Sample Return. But there are two problems with this scenario if MSR is going to be launched in 2018 and 2020.

One problem is that \$68 million in the period from FY'09 to FY'13 is far short of the investment that would be needed to support launch of MSR by 2018 and 2020. Mars Sample Return will be the most complex robotic planetary mission ever undertaken, by a substantial margin. In order to launch the first element of the mission in 2018, our study concluded that a technology investment of hundreds of millions of dollars – not just \$68 million – would have to be made by four or five years before the 2018 launch.

The other problem is the total cost of Mars Sample Return. NASA's stated cost goal for MSR is \$3.5 billion. That number is less than twice the probable cost of the Mars Science Laboratory, for a mission that appears to be much more than twice as complex. We concluded that the full cost of MSR will exceed \$3.5 billion by an amount comparable to an entire flagship mission. That shortfall would have to be covered on the appropriate schedule by a highly capable and committed foreign partner, with all of the management challenges that international partnerships entail.

Putting this together, our study concluded that the President's FY'09 budget request will support NASA's planned Mars missions in 2013 and 2016 only if MSR is slipped well beyond 2020. Alternatively, we concluded that MSR could be carried out by 2020 only if both the 2013 and 2016 missions were eliminated. And at a cost target of \$3.5 billion, we concluded that a flagship-class contribution from a foreign partner would be required to enable sample return.

The impact on the Mars program of elimination of the 2013 and 2016 missions would be severe. There would be a lack of continued progress toward key goals of the NRC Decadal Survey, and a loss of scientific balance. Of perhaps still greater concern is the loss of technical and scientific know-how that could occur as a result of the very long hiatus between landed missions.

In addition, the Mars Exploration Program would cease to be a truly interconnected program of exploration. In a recent report entitled "Grading NASA's Solar System

Exploration Program: A Midterm Review”, the NRC gave the Mars program the only grade of “A” in the review, and said this about it:

A key element of the success of this program is that it is not a series of isolated missions, but rather a highly integrated set of strategically designed missions, each building on the discoveries and technology of the previous missions and fitting into long-term goals to understand the planet, whether or not it ever had or does now have life, and how Mars fits into the origin and evolution of terrestrial planets.

With the implementation of the President’s FY’09 budget request and a Mars Sample Return mission “anchored” in 2020, this key characteristic of the Mars program would be lost.

As I noted at the beginning of my testimony, the President’s budget request for NASA Space Science is a valiant attempt to do a lot with a little. I admire the Agency for this attempt, and I am heartened to see that the budget contains major new initiatives across nearly the full breadth of space science. But I foresee problems, particularly in the weakening of the Agency’s Mars program.

Let me state clearly that the right answer in my opinion is not to move money from other parts of the Space Science budget into the Mars program. Instead, my strongest advice to this committee would be that you work to add to NASA’s Space Science budget the funds necessary to restore the Mars Exploration Program to the levels specified in the FY’08 Congressional Appropriations Act. This would enable NASA to continue what has been one of its most scientifically successful programs. It would also allow continuation of a program that has captured the public’s imagination, and that is directly relevant to the central focus of the Agency: NASA’s Vision for Space Exploration.

If funding cannot be restored to the Mars program, then some very tough choices would have to be made. The way to make such choices, of course, would be via the same kind of community-based process that produced the Decadal Survey. My own opinion is that a post-MSL Mars program that consisted solely of a sample return by 2020 would not be the best use of limited resources. If faced with a decade-long hiatus in the exploration of Mars, I personally feel that the best thing to do about sample return – which has been and remains one of the highest-priority goals of Mars exploration – would be to postpone it a few years in favor of missions in 2013 and 2016 that would continue to make major advances in our knowledge of the planet.

Again, I thank you for the opportunity to appear before the Subcommittee today.