EXPLORING MARS AND BEYOND: WHAT'S NEXT FOR U.S. PLANETARY SCIENCE

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

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HOUSE OF REPRESENTATIVES

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Tuesday, November 15, 2011

EXPLORING MARS AND BEYOND: WHAT'S NEXT FOR U.S. PLANETARY SCIENCE

TUESDAY, NOVEMBER 15, 2011

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:08 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Steven Palazzo [Chairman of the Subcommittee] presiding.

Ralph Hall, Texas
Chairman

Eddie Bernice Johnson, Texas
Ranking Member

U.S. House of Representatives
Committee on Science, Space, and Technology
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Subcommittee on Space and Aeronautics
Exploring Mars and Beyond: What's Next for U.S. Planetary Science
Tuesday, November 15, 2011
10:00 a.m.-12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. Jim Green
Director, Planetary Science Division NASA

Dr. Steve Squyres
Goldwin Smith Professor of Astronomy, Cornell University

HEARING CHARTER

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON SPACE AND AERONAUTICS

Exploring Mars and Beyond: What's Next for U.S. Planetary Science?

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Introduction

On November 25, 2011, NASA will launch the Mars Science Laboratory (MSL). MSL will land a rover—roughly the size of a Mini-Cooper automobile—on the surface of Mars to conduct a variety of experiments that will deepen our understanding of the history of the geological, atmospheric and chemical composition of Mars and inform future missions, including human expeditions. Yet, even as MSL begins its journey to Mars, the follow-on missions in 2016 and 2018—planned jointly with the European Space Agency (ESA)—have been scaled back significantly and could be on the brink of cancellation altogether. Until the Administration delivers its fiscal year 2013 budget request to Congress, NASA is left without definitive answers for our European partners. This uncertainty has left ESA to explore alternative opportunities—perhaps with Russia—or to cancel part of the mission themselves.

The uncertainty surrounding the Mars program highlights a larger issue of the future of U.S. flagship planetary missions. The most recent planetary decadal survey, *Visions and Voyages for Planetary Science in the Decade 2013–2022* lays out a robust program for planetary exploration that includes several top-priority flagship missions—including a Mars sample return mission and a mission to Jupiter's moon Europa. The recommended program does not anticipate that all flagship missions would be pursued. Instead, relative priorities are assigned to assist NASA in making its final programmatic decisions that often include other factors such as technology readiness and budgetary constraints. The report acknowledges this process by emphasizing the necessity for the U.S. to scale these flagship missions appropriately to the anticipated funding in the near term, recommending a significant descoping of these missions to achieve the science objectives less expensively.

The purpose of this hearing will be to receive testimony from NASA and the National Academies of Science on the prospects for future exploration of Mars and implications of the current fiscal crisis to the future of U.S. planetary science. The Office of Management and Budget was invited to testify but chose not to participate.

Witnesses

- *Dr. Jim Green,* Planetary Science Division Director, Science Mission Directorate, National Aeronautics and Space Administration
- *Dr. Steve Squyres,* Chair, Committee on the Planetary Science Decadal Survey, National Academies of Science

Overarching Questions

- What is the current status of the U.S. Mars exploration program? How does Mars Science Laboratory fit into the larger Mars exploration strategy?
- How does NASA's decision to no longer provide the launch vehicle for the 2016 joint NASA/ESA Mars mission and possibly further de-scope participation in the 2018 mission impact NASA's Mars Exploration Program as well as prospects for future international collaboration?
- What is the future prospect for a U.S.-led Mars Sample Return mission, as identified by the most recent National Academies planetary decadal survey as the top priority for planetary science in the coming decade?

- What are NASA's long-term plans for flagship planetary missions? Does the Jupiter Europa Orbiter (JEO) mission have a reasonable chance of being funded?

Background

Since Mariner 4 sent back the first-ever images of Mars in 1965, the American public and indeed the world have been amazed by what we learn about the solar system we live in. The legacy of our spacecraft is rich. In the 1970s, Pioneer 10 & 11 sent never-before-seen pictures of Jupiter and Saturn. Pioneer 10 measured Jupiter's intense radiation belts, located the planet's magnetic field, and discovered that Jupiter is predominantly a liquid planet. After passing by Jupiter, Pioneer 10 continued towards the outer regions of the solar system making valuable scientific investigations until 1997. Pioneer 11 provided valuable data about Saturn, cosmic rays and the solar wind up until 1995. Today, Messenger (MErcury Surface Space ENviroment and Ranging) provides us with the closest ever view of Mercury and it is providing details about the planet's gravity field, mineralology, and atmospheric composition. Juno is en route to study Jupiter in greater detail and GRAIL will provide us with a gravitational map of the moon.

But for all of the discoveries to date, there is still so little we know about our solar system and our neighboring planets. NASA's Planetary Science Division within the Science Mission Directorate builds on previous missions to advance our understanding of the solar systems through progressively more sophisticated missions to planets, moons, comets and asteroids. Its mission is to ″advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.″ Guided by the National Academies of Science decadal survey process, NASA develops a planetary exploration strategy that aims to balance lower-cost, lower-risk missions with higher-cost, greater-risk flagship missions based on the sequence of ″flyby, orbit, land, rove, and return samples″ for each potential destination.

Planetary Decadal Survey Recommendations

The most recent decadal survey, *Visions and Voyages for Planetary Science in the Decade 2013–2022* was issued in March 2011. Requested by NASA, and managed and written by the National Academy of Sciences, the report develops a comprehensive strategy for U.S. planetary science in the coming decade. Per the report, the recommended program "will achieve long-standing scientific goals with a suite of new missions across the solar system. It will provide fundamental new scientific knowledge, engage a broad segment of the planetary science community, and have wide appeal for the general public whose support enables the program."

The decadal report committee utilized four main criteria to measure proposed missions as a means of selecting and prioritizing future missions. First and foremost was the ability to provide high science return per dollar. Programmatic balance across mission targets throughout the solar system as well as the appropriate mix of small, medium and large missions was the second criteria. The other two criteria were technological readiness and the availability of trajectory opportunities within the timeframe discussed.

Flagship Missions

The report concludes that the top-priority large flagship mission for the coming decade would be to establish a three-mission *Mars Sample Return campaign* – one that would not be completed into the decade beyond 2022. That would require completion of the *Mars Astrobiology Explorer-Cacher (MAX-C)*, currently planned as a joint mission with the European Space Agency in 2018.

The ability to afford such a mission, however, was called into question by the report. As of the report's release in March 2011, the MAX-C mission was expected to cost NASA $3.5 billion (in FY2015 dollars) in large part because of an envisioned delivery of two large rovers using a single entry, descent, and landing (EDL) system derived from the Mars Science Laboratory (MSL) EDL system. Such large rovers would require major redesign of the MSL EDL system. The report recommends that NASA pursue a de-scoped mission not to exceed $2.5 billion in order to main program balance (as identified above as part of the selection criteria). As detailed in the Mars Exploration Program description below, NASA has in fact de-scoped the mission and is currently in negotiations with ESA on what the scaled-down mission might look like. Per the report's recommendations, international collaboration is an essential element to affordability and therefore feasibility of such a mission.

Absent a significant de-scope and an appropriate partnership agreement with ESA for a future mission to return collected samples, the report recommends any such Mars collaboration be abandoned for the second priority mission, the *Jupiter*

Europa Orbiter (JEO). Again, however, serious reservations about the cost of the mission came into play. As currently designed, the JEO mission would cost $4.7 billion (in FY2015 dollars), which results in an unacceptable programmatic imbalance by crowding out funding for other planetary missions. The report states:

> *While the committee recommends JEO as the second highest priority Flagship mission, close behind MAX-C, it should fly in the decade of 2013–2022 only if changes to both the mission and the NASA planetary budget make it affordable without eliminating any other recommended missions. These changes are likely to involve both a reduction in mission scope and a formal budgetary new start for JEO that is accompanied by an increase in the NASA planetary budget. NASA should immediately undertake an effort to find major cost reductions for JEO, with the goal of minimizing the size of the budget increase necessary to enable the mission.*

Priorities for Small and Medium Missions

The report does not make specific recommendations on the small Discovery program missions. It does register its continued support for these missions as a valuable asset to the overall program and recommends that it continue at its current level capped at $500 million (FY2015) and a cadence of 24 months for selections.

Medium missions, known as New Frontiers, are capped at $1 billion (FY2015) per mission (excluding launch vehicle costs) with a goal of selecting two such missions in the decade. The report identifies five candidate missions and two alternates for which NASA should select based on competitive peer review. Candidate missions include Comet Surface Sample Return, Lunar South Pole-Aitken Basin Sample Return, Saturn Probe, Trojan Tour and Rendezvous and Venus In Situ Explorer. The alternates would be Io Observer and Lunar Geophysical Network.

Launch Vehicle Costs

The cost of launch services is another challenge to NASA's planetary exploration program. As noted above, the New Frontier missions were capped without including the costs of launch vehicles. This is a departure from previous decadal survey recommendations that absorbed launch costs into total program costs. The decadal survey committee noted the increasing costs of launch vehicles and was concerned with those costs taking a larger share of the overall program costs.

Further exacerbating the launch issue is the planned retirement of the Delta II launch vehicle. The Delta II has been a staple for planetary missions; however, the Air Force terminated its long-standing contract for Delta II's citing budgetary constraints. This decision impacts NASA's ability to use the rocket for future scientific payloads, since it would have to absorb all of the Delta II infrastructure and processing costs which had been paid for by the Air Force. Since the decadal survey was released, NASA modified its NASA Launch Services II contract with United Launch Services to enable up to five additional Delta II rockets per the contract's on-ramp provision. But even with the additional rockets, uncertainty remains. As the report states:

> *The absence of the Delta II will shortly leave a gap in reliable, relatively inexpensive launch capabilities important for missions to the inner planets and some primitive bodies. . . As noted many past missions have relied on the Delta II, and future missions will not have this option. The concern is that alternative launch vehicles of established reliability, such as the Atlas V and the Delta IV, are substantially more expensive even in their smallest versions. The situation is complicated further by the volatility of the costs of these vehicles, and dependence of costs on future contract negotiations. Increases in launch costs pose a threat to formulating an effective, balanced planetary exploration program.*

Need for Plutonium-238

Another area of concern is the availability of Plutonium-238 for future missions. Radioisotope Power Systems (RPSs) utilize heat converted from the nuclear decay of radioactive isotopes to generate electricity. RPSs are frequently used to power spacecraft that travel large distances and in extreme environments. Their ability to operate continuously regardless of their orientation or distance from the Sun make them particularly advantageous. Since 1961, 28 U.S. space missions have safely flown using radioisotope energy sources.

The United States ended production of plutonium-238, the key nuclear component of RPSs in 1988. Separation of the isotope from existing inventories stopped in 1996 leaving the remaining stock of plutonium-238 to be purchased from Russia. Despite no new production, its use continues. Most recently, the Mars Science Laboratory used about 3.5 kg for the Multi Mission Radioisotope Thermoelectric Generator

(MMRTG) and the next Discovery mission has reserved 1.8 kg for two Advanced Stirling Radioisotope Generators (ASRGs).

The decadal survey indicates that in order to complete the recommended program new plutonium-238 production is essential or more deliveries from Russia will be necessary. It concluded:

> *The Committee is alarmed at the status of plutonium-238 availability for planetary exploration. Without a restart of plutonium-238 production, it will be impossible for the United States, or any other country, to conduct certain important types of planetary missions after this decade.*

The fiscal year 2012 president's budget requested $10 million each for NASA and the Department of Energy to enable the U.S. to produce plutonium-238. The House Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies approved the request for NASA in their bill reported out of the full committee on July 7, 2011. Specifically, the bill report states:

> *Plutonium-238.–The bill makes available $10,000,000 from this account, as requested, to restart production of Plutonium-238 (Pu-238), a radioisotope that is an essential source of electrical power for long-range planetary science missions. The Committee urges NASA to work expeditiously with the Department of Energy to bring Pu-238 production back online as quickly as possible while simultaneously pursuing Advanced Stirling Radioisotope Generator technology that will allow NASA to make better, more efficient use of available Pu-238 stocks.*

However, the House Appropriations Subcommittee for Energy and Water denied funding for DOE, citing it as a NASA requirement that should be funded solely by NASA. Specifically, their bill states:

> *Plutonium-238 Production Restart Project.-The National Aeronautics and Space Administration (NASA) uses the vast majority of plutonium-238 (Pu-238) produced or procured by the federal government. The Committee remains concerned that the Administration continues to request equal funding from NASA and the Department of Energy for a project that primarily benefits NASA. The Committee provides no funds for this project, and encourages the Administration to devise a plan for this project that more closely aligns the costs paid by federal agencies with the benefits they receive.*

Likewise, the Senate Appropriations Committee recommended similar action—the subcommittee responsible for NASA provided funding for the project, while the subcommittee responsible for DOE withheld funding.

Current Mars Exploration Program

Scientific discovery of the Red Planet continues thanks to a steady cadence of missions that have built on the sequence strategy of ″flyby, orbit, land, rove and return samples.″

There are several missions currently operating on Mars, all of which are well past their designed mission lifetime.

Mars Odyssey is the longest running spacecraft ever in orbit around another planet. Launched in 2001, the Mars Odyssey quickly discovered evidence of large amounts of water ice just below the surface. Since then, Odyssey has given scientists the opportunity to monitor seasonal changes of the Martian atmosphere and compile lengthy year-to-year comparisons of Martian weather. Odyssey now also serves as a relay service for the Mars Exploration Rovers and is in a prime position to serve as a communications relay for the landing of the Mars Science Laboratory.

The **Mars Exploration Rovers (MER)**—better known as Spirit and Opportunity—have captured the imaginations of the young and old through their ongoing trek across the Martian terrain sending both pictures and valuable information about the history of water on Mars. The rovers were originally slated for a 3-month mission in early 2004. Opportunity continues to send back information to scientists and Spirit only stopped working in 2010.

The **Mars Reconnaissance Orbiter (MRO)** is also providing a valuable look at the history of water on Mars. Launched in 2005, MRO provides images of the surface, mineral analysis, atmospheric measurements and daily weather monitoring. Additionally, MRO provides a critical data and communications link effectively serving as an ″interplanetary Internet″ enabling current and future Mars rovers a communications bridge back to Earth.

Mars Programs Currently in Development

The **Mars Science Laboratory (MSL)** hopes to build on this foundation of knowledge by further examining the Martian environment. Set to launch on November 25, 2011, MSL—better known as Curiosity—will land in August 2012 utilizing a groundbreaking ″sky crane″ landing system. Once on the ground, the small car-sized rover will utilize a suite of scientific cameras and instruments with the objectives of:

- Assessing the biological potential of the site by investigating organic compounds, other relevant elements, and biomarkers
- Characterizing geology and geochemistry, including chemical, mineralogical, and isotopic composition, and geological processes
- Investigating the role of water, atmospheric evolution, and modern weather/climate
- Characterizing the spectrum of surface radiation

The **Mars Atmospheric and Volatile EvolutioN (MAVEN)** mission is currently under development and scheduled to launch in late 2013. MAVEN was selected under NASA's Mars Scout program, which supports smaller, low-cost competed missions led by a principal investigator. MAVEN seeks to obtain measurements of the Martian atmosphere in order to gain a better understanding of the climate changes that have occurred over the planet's history.

Joint NASA-ESA Mars Missions

The United States originally planned to partner with the European Space Agency on a joint two-phase mission that would build on the previous work of both U.S. and European exploration of Mars and lay the framework for an eventual sample return mission.

The first mission, **ExoMars Trace Gas Orbiter**, is currently scheduled to launch in 2016. The mission includes an orbiter with several science instruments including the ability to monitor methane or other trace atmospheric gasses. It would also be a demonstration for Europe to test entry, descent and landing (EDL) capabilities to the surface. In addition to collaborating on the science instruments on the orbiter, NASA would launch the mission on an Atlas V rocket. In September 2011 NASA informed ESA that the U.S. would no longer be able to afford the rocket to launch the 2016 mission. ESA has subsequently solicited participation from the Russian Space Agency, Roscosmos, for the 2016 mission to include a possible launch on a Proton rocket. This solicitation has also opened up the possibility of Russian participation on the orbiter instruments.

The second **NASA-ESA ExoMars/MAX-C** mission was to send in 2018 two rovers—one led by the U.S. and the other by Europe—to operate in separate but complementary missions. The rovers would be armed with a drill and a storage cache to collect suitable samples for a future return mission. The mission is planning to utilize the EDL technologies developed for MSL and also be launched by the U.S. on an Atlas V rocket.

The current budget situation in the United States, however, has led NASA to reconsider its obligations to ESA under the currently signed agreement. In April 2011, NASA and ESA agreed to send only one rover that would combine the research and storage components of the previously separate rovers.

A meeting between the two agency heads in October 2011 left even further questions about the future of both the 2016 and 2018 missions on the table. NASA was unable to make any commitments to ESA prior to the official fiscal year 2013 president's budget proposal due out in February 2012. Without a clear agreement with NASA, ESA is conducting its own analysis of alternatives.

ESA continues to provide funding for the 2016 mission even as discussions open the up the possibility of combining the entire mission into one launched only in 2018. ESA has already secured approximately 850 million of the needed 1 billion Euros needed to meet ESA's commitments for the two-launch mission from its member states. ESA has indicated that even if the mission were to be de-scoped to a single launch, it would still need about the same amount of money due to already obligated funds.

Budget Outlook

The fiscal year 2012 budget request for NASA's Planetary Science Division is $1.54 billion.

The House Appropriations Committee approved a FY12 budget for NASA on July 7, 2011. The final report did not provide a specific recommendation for planetary science funding, but reduces the overall Science Mission Directorate budget by $512,800,000 below the president's request (recommending $4,504,000,000, which is $431,409,000 below fiscal year 2011). Report language provides specific language regarding flagship missions by saying:

> *Planetary Science missions.*–The Committee accepts the findings of the most recent Planetary Science decadal survey and supports the application of the survey's decision rules to determine how best to structure the program within the available budget. The program elements most significantly impacted by these decision rules are the flagship missions, which must be substantially descoped in order to remain within the portfolio. The Committee directs that $4,000,000 of the Outer Planets Flagship (OPF) budget be used to conduct the necessary descoping studies for the decadal survey's two highest priority flagship missions: Mars Sample Return (MSR) and the Jupiter Europa Orbiter (JEO). The results of these studies shall be transmitted to the Committee as soon as they are complete. The remaining $39,000,000 of OPF funds should be held pending the completion of the descoping analysis and, depending on the results, either used in support of an acceptably descoped flagship mission or proposed for reprogramming to other Planetary Science project lines in accordance with the decadal survey's decision rules.

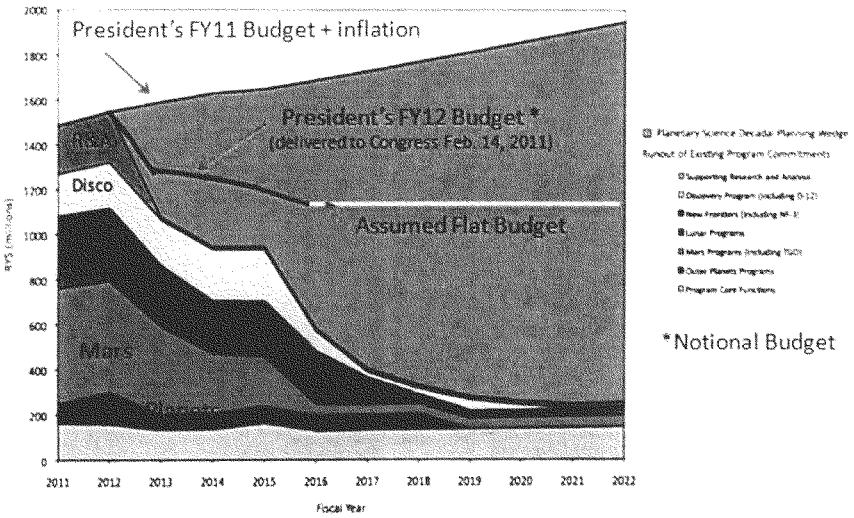
The Senate approved its FY12 budget for NASA on November 1, 2011 providing $1.5 billion for Planetary Science. *See Appendix A for a complete breakdown by mission area.* In its report, the committee states:

> The Committee notes that the most recent decadal survey in planetary science urges NASA to reformulate planetary science flagship missions to fit within the projected budget, as recommended. The NASA budget, like the Federal budget overall, is shrinking, not growing.

The following chart, provided by NASA, illustrates the constraints the division is currently under and dramatically demonstrates the downward pressure on the future budget for planetary science.

9

Planetary Funding Profile
Issued Prior to the Planetary Decadal



Red area is what was available for the next decadal programs from Presidents FY11 budget

*Source: NASA

APPENDIX A

Planetary Science FY12 Budget Comparison – Senate Version vice President's Request

Planetary Science FY12 Budget	Senate	President's Request	Delta
Planetary Science Research	**189,500.00**	**192,100.00**	**(2,600.00)**
Planetary Science Research and Analysis	139,000.00	140,900.00	(1,900.00)
Other Missions and Data Analysis	25,000.00	25,300.00	(300.00)
Education and Directorate Management	5,300.00	5,400.00	(100.00)
Near Earth Object Observations	20,200.00	20,400.00	(200.00)
Lunar Quest Program	**129,600.00**	**129,600.00**	**-**
Lunar Science	54,400.00	54,400.00	-
Lunar Atmosphere and Dust Environment Explorer	71,800.00	71,800.00	-
International Lunar Network	3,400.00	3,400.00	-
Discovery	**176,800.00**	**179,100.00**	**(2,300.00)**
Gravity Recovery and Interior Laboratory [GRAIL]	40,800.00	40,800.00	-
Other Missions and Data Analysis	136,000.00	138,300.00	(2,300.00)
New Frontiers	**176,400.00**	**181,800.00**	**(5,400.00)**
Juno	31,400.00	31,400.00	$ -
Other Missions and Data Analysis	145,000.00	150,400.00	(5,400.00)
Mars Exploration	**581,700.00**	**602,200.00**	**(20,500.00)**
2009 Mars Science Lab	138,000.00	138,000.00	-
MAVEN	245,700.00	245,700.00	-
Other Missions and Data Analysis	198,000.00	**218,600.00**	(20,600.00)
Outer Planets	**117,100.00**	**122,100.00**	**(5,000.00)**
Technology	**129,300.00**	**133,900.00**	**(4,600.00)**
Subtotal, Planetary Science	**1,500,400.00**	**1,540,700.00**	**(40,300.00)**

Chairman PALAZZO. The Subcommittee on Space and Aeronautics will come to order.

Good morning. Welcome to today's hearing entitled "Exploring Mars and Beyond: What's Next for the U.S. Planetary Science." In front of you are packets containing the written testimony, biographies and, Truth in Testimony disclosures for today's witness panel. At this time I will recognize myself for five minutes for an opening statement.

Today's hearing has been called to examine the future course of NASA's Planetary Sciences program, looking particularly at NASA's plans to carry out recommendations put forward in the Decadal Survey released earlier this spring by the National Academy of Sciences.

Before getting started, however, I would like to thank our witnesses for agreeing to testify today. I realize a lot of work and effort goes into preparing for your appearance, and I want you to know that your wisdom and experience will be of immense value to this Committee and Congress in the months and years ahead as we strive to maintain a vital national space program.

In March of this year, the National Academy of Sciences published Visions and Voyages for Planetary Science in the Decade 2013–2022. This report reflects a broad consensus of the planetary science community, first by identifying key questions to guide NASA in the decade ahead as it endeavors to develop the next series of missions, and then by providing NASA the tools needed to maintain a balanced and vital program that looks broadly across our solar system. It is the product of an immense effort that sought a wide range of input, including papers, meetings and reviews by a committee chaired by Dr. Steven Squyres.

Unfortunately, budget forecasts provided by NASA to the Academy proved to be optimistic. To its credit, the survey committee had the foresight to anticipate budget shortfalls and included in their recommendations steps that the agency should follow to align programs with resources, all the while maintaining balance across a set of missions.

For fairly obvious reasons, exploration of Mars has become the largest component of NASA's Planetary Science program, as well as one of its most visible. Through development of critical technologies, NASA has orbited the planet with powerful satellites, put rovers on its surface, and in less than two weeks' time NASA is preparing to launch yet another rover that will be bigger and more capable still.

The conundrum now facing NASA is selecting a mission that is the next logical step in our exploration of Mars, and how to pay for it. The Decadal Survey selected as its top priority mission a Mars sample-caching rover that would, in effect, be the first of a three-phase mission to return Mars soil samples to Earth. This will be a very expensive undertaking, and one obvious option would be to engage with the European Space Agency on a collaborative mission, thus reducing costs to the United States.

In November 2009, NASA Administrator Bolden and ESA Director General Dordain signed a joint Statement of Intent that spelled out a series of steps for the exploration of Mars that both agencies, working collaboratively, hoped to pursue. Quoting from the state-

ment: "NASA and ESA agree to consider the establishment of a new joint initiative to define and implement their scientific, programmatic and technological goals for the exploration of Mars."

Initially focusing on 2016 and 2018, this initiative would span several launch opportunities with landers and orbiters conducting astrobiological, geological, geophysical, climatological and other high-priority investigations and aiming at returning samples from Mars in the mid-2020s.

So the question is, are we ready to make that commitment? Will NASA be a reliable partner, able to sustain obligations that span years, Administrations, and unpredictable budgets? If not resolved quickly, I am deeply worried that NASA will be viewed by our international partners as an unreliable, schizophrenic agency. On the one hand NASA is actively seeking international partners to collaborate on future missions; on the other, the Administration appears to be interfering with the agency's efforts to reach out and engage foreign governments in future flagship missions. If these internal conflicts aren't soon resolved, NASA could be left alone to fly its own missions with budgets that will result in fewer flight opportunities. Meanwhile, other international space agencies will collaborate, and in time, they may well be able to fly space missions that were once the domain of NASA.

Adding further uncertainties are NASA's struggles with the James Webb Space Telescope. To its credit, NASA identified offsets across the Science Mission Directorate, including Planetary Science, but did it in a way that did not undermine its ability to proceed with a descoped Mars sample-caching rover. Unfortunately, the White House has not yet approved the plan for release, preventing NASA from living up to its commitments to ESA, and frustrating our European partners. Adding further insult, the White House won't even reveal what offsets will be taken out of Planetary Science's fiscal year 2012 budget, suggesting that they will wait until next February with the fiscal year 2013 budget request rollout to identify offsets in the fiscal year 2012 operating plan. I can't begin to make sense of the rationale for such a delay.

Before closing, I also want to stress the importance of maintaining balance in the Planetary Science portfolio, both in terms of mission size and destination. NASA must ensure that flagship missions don't overwhelm the Planetary Science budget, as well as preserve a regular cadence of small to medium size missions.

I realize my statement has covered a lot of territory, but in today's environment, discussing future Planetary Sciences missions necessarily involves agency budgets, international partners, the planetary science community, and the James Webb Space Telescope.

I want to point out that the Office of Management and Budget was invited to testify at this hearing, but chose not to appear. I am not surprised, but I find it regrettable. OMB has enormous influence over NASA, as their decisions in many ways define the agency's future roles and missions. It would have been helpful to gain their perspective in these discussions.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF STEVEN M. PALAZZO, SUBCOMMITTEE CHAIRMAN

Today's hearing has been called to examine the future course of NASA's Planetary Sciences program, looking particularly at NASA's plans to carry out recommendations put forward in the Decadal Survey released earlier this spring by the National Academy of Sciences.

Before getting started, however, I'd like to thank our witnesses for agreeing to testify today. I realize a lot of work and effort goes into preparing for your appearance, and I want you to know that your wisdom and experience will be of immense value to this Committee and Congress in the months and years ahead as we strive to maintain a vital national space program.

In March of this year the National Academy of Sciences published *Visions and Voyages for Planetary Science in the Decade 2013–2022.* This report reflects a broad consensus of the Planetary Science community, first by identifying key questions to guide NASA in the decade ahead as it endeavors to develop the next series of missions, and then by providing NASA the tools needed to maintain a balanced and vital program that looks broadly across our solar system. It is the product of an immense effort that sought a wide range of input, including papers, meetings, and reviews by a committee chaired by Dr. Steven Squyres.

Unfortunately, budget forecasts provided by NASA to the Academy proved to be optimistic. To its credit the survey committee had the foresight to anticipate budget shortfalls and included in their recommendations steps that the agency should follow to align programs with resources, all the while maintaining balance across a set of missions.

For fairly obvious reasons, exploration of Mars has become the largest component of NASA's Planetary Science program, as well as one of its most visible. Through development of critical technologies, NASA has orbited the planet with powerful satellites, put rovers on its surface, and in less than two weeks time is preparing to launch yet another rover that will be bigger and more capable still.

The conundrum now facing NASA is selecting a mission that is the next logical step in our exploration of Mars, and how to pay for it. The decadal survey selected as its top priority mission a Mars sample-caching rover that would, in effect, be the first of a three-phase mission to return Mars soil samples to Earth. This will be a very expensive undertaking, and one obvious option would be to engage with the European Space Agency on a collaborative mission, thus reducing costs to the US.

In November 2009, NASA Administrator Bolden and ESA Director General Dordain signed a joint Statement of Intent that spelled out a series of steps for the exploration of Mars that both agencies, working collaboratively, hoped to pursue. Quoting from the statement: ″NASA and ESA agree to consider the establishment of a new joint initiative to define and implement their scientific, programmatic, and technological goals for the exploration of Mars. Initially focusing on 2016 and 2018, this initiative would span several launch opportunities with landers and orbiters conducting astrobiological, geological, geophysical, climatological, and other high-priority investigations and aiming at returning samples from Mars in the mid-2020s.″ So the question is, are we ready to make that commitment? Will NASA be a reliable partner, able to sustain obligations that span years, Administrations, and unpredictable budgets?

If not resolved quickly, I am deeply worried that NASA will be viewed by our international partners as an unreliable, schizophrenic agency. On the one hand NASA is actively seeking international partners to collaborate on future missions; on the other, the Administration appears to be interfering with the agency's efforts to reach out and engage foreign governments in future flagship missions. If these internal conflicts aren't soon resolved, NASA could be left alone to fly its own missions with budgets that will result in fewer flight opportunities. Meanwhile other international space agencies will collaborate, and in time, they may well be able to fly space missions that were once the domain of NASA.

Adding further uncertainties are NASA's struggles with the James Webb Space Telescope. To its credit, NASA identified offsets across the Science Mission Directorate—including Planetary Science—but did it in a way that did not undermine its ability to proceed with a de-scoped Mars sample-caching rover. Unfortunately, the White House has not yet approved the plan for release, preventing NASA from living up to its commitments to ESA, and frustrating our European partners. Adding further insult, the White House won't even reveal what offsets will be taken out Planetary Science's FY12 budget, suggesting that they'll wait until next February with the FY13 budget request rollout to identify offsets in the FY12 operating plan. I can't begin to make sense of the rationale for such a delay.

Before closing, I also want to stress the importance of maintaining balance in the Planetary Science portfolio, both in terms of mission size and destination. NASA

must ensure that flagship missions don't overwhelm the Planetary Science budget, as well as preserve a regular cadence of small to medium size missions.

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Chairman PALAZZO. I now recognize our Ranking Member, Ms. Edwards, for her opening statement.

Ms. EDWARDS. Thank you very Chairman Palazzo, and thank you for holding the hearing today to receive testimony on the prospects for future exploration of Mars and the implications of the current fiscal environment on the future of U.S. planetary science.

Over the past 15 years, NASA has carried out a systematic exploration of Mars using orbiting spacecraft, landers and rovers. These missions have resulted in dramatic changes in our understanding of the planet, its potential to harbor life, and our ability to eventually carry out human exploration of Mars. They have also established the United States as the undisputed leader in Mars exploration. The United States is the only Nation is the world that is capable of successfully landing and operating a spacecraft on Mars. Our Mars exploration program has been a scientific success story. It is the envy of the world and it has inspired countless young people to pursue education and careers in science and technology.

What we don't know is whether or how that story of success will continue, and especially whether the United States will retain its leadership role. While the Mars Science Laboratory rover, Curiosity, is set to launch in less than two weeks, the future of the U.S. Mars exploration program is quite unclear.

Given the extremely difficult fiscal challenges facing our Nation, international collaboration, as recommended by the National Academy of Sciences' Planetary Science Decadal Survey, would seem to be a sensible path forward that will allow the United States to sustain systematic exploration and pursue the top-priority large mission, Mars Sample Return. Indeed, the President's national space policy also calls for such international collaborations in space activities. Building on their longstanding international partnership in space science, NASA and ESA, the European Space Agency, planned a joint initiative to collaborate on a series of future Mars missions. However, the status of that initiative now appears to be in question.

In order to keep the vitally important James Webb Space Telescope on track, NASA will need to find an additional $1.2 billion over the next five years from within its science and agency operations budget. Decisions on how those science budget offsets will be made have significant implications for the future of the Mars program. Reportedly, OMB officials are overruling the scientific experts at NASA on how those offsets should be best allocated across the agency's science programs, with the result that NASA's long-planned joint NASA–ESA Mars program appears to be in serious jeopardy. If these reports are accurate, such action by OMB is a se-

rious cause for concern, and I too would like to hear from OMB about that. This Subcommittee needs to find out whether those reports are accurate. And if they are not, we need to find out what is holding up NASA's plans to move forward with ESA.

I certainly want to make sure that NASA works vigorously to make sure that costs are kept under control as the agency embarks on the joint Mars program. Strategies to instill cost discipline on expensive missions can certainly be put into place, and we must be careful to avoid shortsighted, bureaucratic decisions that can end up dismantling a highly successful program and skilled workforce, jeopardizing U.S. leadership, and retreating from a carefully constructed international partnership. The results of ill-conceived decisions, bureaucratic decisions, cannot be easily recovered at some later date, and we have to place a priority, I think, on the science.

So I hope to hear from each of our witnesses today on the following. Has NASA's science program developed a credible plan to accommodate the cost growth of James Webb that will enable NASA to pursue the long-planned joint Mars initiative with the European Space Agency? What is preventing NASA from being able to move forward and commit to the partnership on the 2016 and 2018 joint Mars missions, and what is needed to get things moving? What is at stake if the United States doesn't commit to moving forward with ESA on Mars?

I look forward to hearing the responses to these questions and others from the testimony of our witnesses today, and I thank you for being here and thank you, Mr. Chairman, for your indulgence with my tardiness.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF DONNA EDWARDS

Chairman Palazzo, thank you for holding today's hearing to receive testimony on the prospects for future exploration of Mars and the implications of the current fiscal environment on the future of U.S. planetary science.

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how those offsets should best be allocated across the agency's science programs, with the result that NASA's long-planned joint NASA-ESA Mars program appears to be in serious jeopardy. This action by OMB is a serious cause for concern.

This Subcommittee needs to find out whether those reports are accurate. And if they are not, we need to find out what is holding up NASA's plans to move forward with ESA. I certainly want to make sure that NASA works vigorously to make sure that costs are kept under control as the agency embarks on the joint Mars program. Strategies to instill cost discipline on expensive missions can certainly be put into place. We must be careful to avoid short-sighted, bureaucratic decisions that can end up dismantling a highly successful program and skilled workforce, jeopardizing U.S. leadership, and retreating from a carefully constructed international partnership. The results of ill-conceived decisions cannot be easily recovered from at some later date.

So I hope to hear from each of our witnesses today on the following:

1. Has NASA's Science program developed a credible plan to accommodate the cost growth on James Webb that will enable NASA to pursue the long-planned joint Mars initiative with ESA?
2. What is preventing NASA from being able to move forward and commit to the partnership with ESA on the 2016 and 2018 joint Mars missions, and what is needed to get things moving?
3. What's at stake if the U.S. doesn't commit to moving forward with ESA on Mars?

I look forward to hearing the responses to these questions and the testimonies of our witnesses today.

Chairman PALAZZO. Thank you, Ms. Edwards.

At this time I will yield to the Chairman of the Science, Space, and Technology Committee for a brief opening statement. Mr. Hall.

Chairman HALL. Thank you, Mr. Palazzo, and I thank you for calling this hearing to examine NASA's planetary science program.

I can't think of a more exciting and successful robotic space program that has electrified so many of our people, young and old, with images and discoveries about the solar system in which we live: the Mars exploration rovers, the Cassini mission is still returning incredible data and pictures from Saturn, the Galileo mission that orbited Jupiter and to me one of the most notable achievements are the Voyager satellite that were launched in 1977 and still operating today and are the farthest manmade objects lofted from Earth.

There are so many other remarkable missions I didn't name but the point is that NASA's Planetary Science program has accomplished so very much and has helped stake NASA's claim as one of the world's leading science and exploration institutions, and it is important that we work together to maintain this string of exciting missions for the next generation to enjoy the wonderment of science.

There is, of course, the business side to attend to during today's hearing, and I don't mean to distract from that task but I just want to thank our witnesses for being here and to urge NASA, the Administration, the science community and Congress to sustain this noble enterprise. I only wish they worked as hard at keeping the space station as they have in this program.

I yield back.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF CHAIRMAN RALPH M. HALL

Mr. Palazzo, thank you for calling today's hearing to examine NASA's Planetary Science Program. I can't think of a more exciting and successful robotic space pro-

gram that has electrified so many of our people, young and old, with images and discoveries about the Solar System in which we live.

The Mars Exploration Rovers; the Cassini mission that is still returning incredible data and pictures from Saturn; the Galileo mission that orbited Jupiter; and to me, one of the most notable achievements are the Voyager satellites that were launched in 1977 and still operating today, and are the farthest man-made objects lofted from Earth. There are so many other remarkable missions I didn't name, but the point is that NASA's Planetary Science program has accomplished so much, and has helped stake NASA's claim as one of the world's leading science and exploration institutions.

And it's important that we work together to maintain this string of exciting missions for the next generation to enjoy the wonderment of science.

There is, of course, the business side to attend to during today's hearing, and I don't mean to distract from that task. But I just wanted to thank our witnesses for being here, and to urge NASA, the Administration, the science community, and Congress to sustain this noble enterprise.

Chairman PALAZZO. Thank you, Mr. Chairman.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Before proceeding with the introduction of witnesses, I would like to ask unanimous consent to enter into the record written statements submitted by the Planetary Society, the European Space Agency, and by Dr. Mark Sykes, CEO and Director of the Planetary Science Institute. Hearing no objection, so ordered.

[The information appears in Appendix II:]

Chairman PALAZZO. At this time I would like to introduce our witness panel. Our first witness is Dr. Jim Green, Director of Planetary Science Division of NASA. Dr. Green began his career in NASA's Marshall Space Flight Center in 1980. In 1985, he transferred to the Goddard Space Flight Center, where he served as Chief of the Space Science Data Operations Office as well as Chief in the Science Proposals Support Office. He also served as a Co-Investigator and Deputy Project Scientist on the IMAGE Mission. In August 2006, Dr. Green was named Director of the Planetary Science Division. Dr. Green received his Ph.D. in space physics at the University of Iowa. Welcome, Dr. Green.

Our second witness is Dr. Steven Squyres, the Goldwin Smith Professor of Astronomy at Cornell University. Dr. Squyres received his Ph.D. from Cornell in 1981 and spent five years working at Ames Research Center before returning to his alma mater as a faculty member. Dr. Squyres has participated in many of NASA's planetary missions including the Voyager mission to Jupiter and Saturn, the Magellan mission to Venus, and most recently, as Principal Investigator for the science payload on the Mars exploration rover project. Dr. Squyres served as Chair of the Planetary Decadal Survey for the National Research Council, and within just the last two weeks was named as Chair of the NASA Advisory Committee. Dr. Squyres, thank you for joining us today.

As our witnesses should know, spoken testimony is limited to five minutes each after which the Members of Congress will have five minutes each to ask questions.

I now recognize our first witness, Dr. Jim Green, Planetary Science Division Director of the Science Mission Directorate in NASA.

STATEMENT OF DR. JAMES GREEN, DIRECTOR, PLANETARY SCIENCE DIVISION, MISSION DIRECTORATE, NASA

Dr. GREEN. Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today to testify concerning the NASA's Planetary Science program, our plans to implement the National Academy of Sciences' Planetary Decadal Survey, and our joint Mars exploration program with the European Space Agency, or ESA.

We are in the midst of what we call at NASA and our planetary science community call the Year of the Solar System. This current 670-day period—it is a Mars year, after all—is chockfull of astounding scientific results and amazing accomplishments of many of our planetary missions to a wide variety of bodies throughout the solar system. My written testimony summarizes these for you.

In my brief few minutes here, I will only say that the capstone of the Year of the Solar System activity is the launch and landing of the Mars Science Laboratory and its rover Curiosity on the surface of Mars. MSL now sits on top of its launch vehicle awaiting its launch window opening on November 25th, and for me, Thanksgiving will occur after a successful launch.

Looking to the future, NASA is committed to the National Academy of Sciences' Planetary Decadal Survey in planning the future of our planetary science program. We take the Planetary Science Decadal Survey very seriously because it represents a broad national science community consensus. The Planetary Science Decadal assures the progress on our highest priority science questions and keeps NASA and the planetary science community focused on these objectives.

The survey recommends NASA conduct a balanced mix of missions:Discovery, New Frontier, and flagship missions. The survey's highest priority flagship mission is a Mars 2018 rover and sample-caching mission as a first step in a Mars science sample return campaign. It can only be done, as the decadal survey states, if NASA is able to reduce the cost to less than $2.5 billion. The survey further recognizes the need for Mars 2016 and 2018 missions to proceed together, and the survey recognizes that NASA must move forward with these, only with these to accomplish these missions.

NASA has been studying approaches to return samples from Mars to Earth for well over a decade, and now the science community is ready and eager for us to get started as delineated in the new Planetary Science Decadal Survey. Since 2007, NASA and ESA have been planning Mars sample return concepts together. The joint effort led to a 2009 Statement of Intent signed by the NASA Administrator and Director General of ESA on a joint Mars robotic exploration program, and this includes Mars 2016 and 2018 missions. We are working extensively with ESA since the 2009 agreement to define a program to accomplish these missions within the available budget. The results of this effort must be ready soon if we are to make the 2016 launch window and to enable the NASA/ESA partnership to move forward.

The decadal survey's second priority flagship is a Jupiter Europa mission. This orbiter, as the decadal survey recognizes, or JEO, Jupiter Europa Orbiter, would cost approximately $4.7 billion, far

more than the available budget for a planetary flagship mission, and so the decadal recommends to NASA to undertake a redefined JEO mission at a cost that would minimize the size of the budget necessary to be increased to enable this mission. That JEO mission concept study is well underway and should be completed late next spring.

The survey's third priority flagship mission is a Uranus orbiter and probe, and rounding out the list are an Enceladus orbiter and a Venus climate orbiter.

Currently, NASA is working to define an approach with ESA to implement the highest priority flagship. Overall, we are working to define a flagship mission that can be implemented in this decade in the context of a balanced mix of mission sizes and classes recommended by the decadal.

I would like to take this opportunity now to publicly thank Dr. Steve Squyres for his leadership of the academy committee that produced the planetary decadal survey. It is providing us a tremendous valuable guide in planning our future planetary science portfolio as we knew it would be.

Thank you for the opportunity to appear before this Committee today, and I am pleased to answer any questions you may have.

[The prepared statement of Dr. Green follows:]

PREPARED STATEMENT OF DR. JAMES GREEN, DIRECTOR,
PLANETARY SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to discuss the accomplishments, status, and future direction of NASA's Planetary Science program and, in particular, the Mars Exploration Program. NASA's Planetary Science program has produced a long series of visible and exciting triumphs of American science, engineering, and exploration leadership. NASA spacecraft have visited every planet in our solar system, as well as many of the variety of small bodies such as comets and asteroids that have much to tell us about the solar system's formation. So many of our past and current efforts are coming to fruition in the near future that NASA thinks of the period from October 2010 through August 2012—the length of one Martian year—as the Year of the Solar System.

Recent Accomplishments and Current Missions

NASA's current Planetary Science missions in space are returning imagery and data that are revolutionizing our understanding of our solar system's history and its potential habitability—past, present or future.

- Planetary missions Deep Impact and Stardust, whose prime missions were completed, were retargeted to two comet bodies: Hartley 2 and Tempel 1. Surprisingly, Hartley 2 was found to spew basketball and smaller sized snowballs of cometary material. Scientists now recognize that this comet is near its evolutionary end state of completely dissipating into the solar system. By revisiting Tempel 1, we obtained new views of how the comet evolved after its perihelion passage and obtained information on the region previously impacted during the Deep Impact flyby.
- MESSENGER arrived in orbit around Mercury last March. Since then, it has found that Mercury's magnetic field is offset far to the north of its core—a feature we cannot now explain. MESSENGER is exploring surface features scientists are calling "hollows" that indicate they may be actively forming today.
- Launched in September 2011, the GRAIL mission to reveal the structure of the interior of Earth's moon arrives in lunar orbit on New Year's Eve and will conduct its science mission through the first half of 2012.
- Launched in August 2011, the Juno mission to Jupiter is on its way to an arrival in 2016. During its one-year mission in polar orbit, Juno will draw a detailed picture of Jupiter's magnetic field and find out whether there is a solid core beneath its deep atmosphere.

- The Dawn spacecraft is currently in orbit around the asteroid Vesta. There it found that Vesta's southern hemisphere boasts one of the highest mountains in the solar system, three times the height of Mt. Everest. The striations encircling Vesta and other features point to a giant impact with another body. Dawn will depart Vesta in mid-2012 on its journey to Ceres so it can compare these two large asteroids that appear to have dramatically different histories.
- Cassini continues its long reconnaissance of Saturn and its moons, and will do so through 2017. Cassini has observed aurorae and seasonal change on Saturn and Titan its largest moon. It has observed water and organic molecules ejected from geysers on the southern reaches of the small moon Enceladus. And Cassini has found that the giant moon Titan has rain and lakes-not of water but of methane and ethane-making it much like what we believe the early Earth was like.
- The New Horizons spacecraft will flyby Pluto in 2015-the first mission to do so-and will continue into the Kuiper Belt that comprises many Pluto-like objects. In 2010, the spacecraft passed its halfway point.
- OSIRIS-REx will be the next mission in our New Frontier Program, the first U.S. mission to return samples from an asteroid back to Earth.
- The next Discovery mission will be selected from the following candidates: a geophysical monitoring station on Mars; a mission to land a boat in a lake on Titan; and mission to land on a comet multiple times and observe changes as it approaches the Sun.
- At Mars, we have several missions in operation, recently completed, or in development. NASA has long had a strategic, multi-mission approach to thoroughly investigating Mars with a scope, intensity, and duration exceeded only by our study of planet Earth. That is because, beyond Earth, Mars is the most likely and most accessible place to look for signs of life in the solar system. And so we want to study its atmosphere and geology to understand Mars' past, present, and future potential to harbor life.
    - Currently in orbit around Mars are the Mars Reconnaissance Orbiter (MRO) and the Mars Odyssey, which have revealed tantalizing features that appear to have been shaped by water flowing on the surface in the past. We have recently found evidence of briny liquid water flows that disturb the surface of some areas on a seasonally variable basis. MRO imagery was crucial in selecting the landing site for the Mars Science Laboratory.
    - The Mars Exploration Rover Spirit, which ceased operation in March 2011, made the first close-up inspection of water-altered rocks and carbonates. In August, the Mars Exploration Rover Opportunity reached Endeavor Crater. This crater, about the size of the beltway around Washington, DC, contains clay minerals that may hold clues to an ancient, habitable environment in the early, wet Noachian epoch of Mars.
    - The Mars Atmosphere and Volatile Evolution (MAVEN) mission in development for launch in 2013 will help us understand how and why the Martian atmosphere transitioned from the denser, wetter atmosphere of its past to the thinner, dryer one we see today.
    - The Mars 2016 Trace Gas Orbiter, planned as part of the ESA-US ExoMars Mission concept (Mars 2016 and Mars 2018) currently under review, is designed to investigate the seasonally variable concentrations of methane and other gases in the Martian atmosphere and attempts to determine their origins.

Capping this Year of the Solar System, the Mars Science Laboratory (MSL) now sits on top of its Atlas V launch vehicle on its launch pad, with final preparations for launch on track for the opening of the launch window on November 25th. The Mars Science Laboratory rover, named Curiosity, is the next long stride forward in our scientific exploration of the Martian surface. The Curiosity rover will analyze dozens of samples scooped from the soil, drilled from rocks, and pulled from the atmosphere. MSL is designed to seek to determine the planet's habitability-that is, whether it ever did or whether it could support life. Curiosity's ability to detect and characterize organic compounds, and determine where the "signs of life" might be preserved, will be vital to the selection of instruments and landing site for any other mission involving landing on the Red Planet.

NASA's Planetary Science program over the past decade has been a balanced program of competed missions such as those selected through the Discovery and New Frontiers program, and strategic missions such as Cassini and most of the Mars

missions. Mars has warranted special attention because of its potential to answer the broadest range of questions concerning solar system history and habitability.

Planning the Future of Planetary Science – Implementing The Decadal Survey

NASA uses the recommendations of the National Academy of Sciences' Decadal Survey in planning the future of our Planetary Science program in the climate of a constrained Federal budget. Decadal surveys have proven indispensable in establishing a broad national science community consensus on the state of the science, the questions to be addressed, and most importantly, a prioritized list of candidate actions and mission concepts to be pursued or studied over the decade. NASA contracts with the National Academy of Sciences to prepare decadal surveys in all four science areas of NASA's Science Mission Directorate: Astrophysics, Earth Science, Heliophysics, and Planetary Science.

NASA received a new Planetary Science Decadal Survey in March 2011. This survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022* (NRC, 2011), is the product of hundreds of eminent planetary scientists from around the Nation. NASA is extremely grateful to Dr. Steven Squyres for his superb leadership of the Academy committee that authored the Survey report.

The new Planetary Science Decadal Survey has three features that make it an effective guide for NASA and the Nation's planning. First, it recommends a balanced program, and defines what "balanced" means in terms of the relative levels of investment in small, medium, and large (or flagship) missions, technology development, and research & analysis. Second, it defines a priority order for flagship mission concepts, subject to NASA's ability to define mission concepts that fit their expected budget envelope. Third, it defines a set of decision rules to help NASA make decisions under different budget outlook scenarios. This latter feature is proving especially useful, as the budget outlook is less optimistic than the Survey assumed for either their "Recommended Program" or "Cost-constrained Program" options.

The Survey's first recommendation is that:

> "NASA's suite of planetary missions for the decade 2012–2022 should consist of a balanced mix of Discovery, New Frontiers, and Flagship missions, enabling both a steady stream of new discoveries and the capability to address larger challenges like sample return missions and outer planet exploration."

The Survey also identified "the need to maintain programmatic balance by assuring that no one mission takes up too large a fraction of the planetary budget at any given time." NASA is planning its Planetary Science portfolio accordingly and using the Planetary Science Subcommittee of the NASA Advisory Council for guidance and feedback on our specific implementation plans.

The Survey's highest priority flagship mission is a Mars sample-caching mission. The Survey identified this as the highest priority flagship if three conditions pertain: 1) it is to begin the NASA-European Space Agency Mars Sample Return campaign; 2) NASA must be able to implement its portion of the mission at a cost to NASA of no more than approximately $2.5 billion; and, 3) the mission must be launched by 2018. NASA is working with ESA to define a mission that meets these criteria and can be accommodated within anticipated resources.

Following the Mars sample-caching mission, the next highest priority flagship mission is the Jupiter Europa Orbiter. Europa and Mars Sample Return were both in the prior Decadal Survey (from 2002), and, thus, NASA has a long history of studying Europa mission concepts. Here again, NASA had been coordinating with ESA on these studies and, prior to the recent Decadal Survey, had been studying a joint two-satellite Jupiter System Mission. Given the cost of the Europa mission, estimated by the Survey at $4.7 billion, the Survey recommended that:

> "NASA should immediately undertake an effort to find major cost reductions for JEO, with the goal of minimizing the size of the budget increase necessary to enable the mission."

NASA is currently conducting such a study with this objective. The third priority flagship mission in the Survey is a Uranus Orbiter and Probe mission. Rounding out the Survey's list of flagship candidates are an Enceladus Orbiter and a Venus Climate Mission.

The Decadal Survey also recommended that NASA continue to allow Discovery missions to be proposed to Mars. In fact, NASA is currently supporting development of a mission concept for a Mars geophysical monitoring station as one of three in competition to be the next Discovery mission. This mission would collect data on the

interior of Mars. Other than the Earth and to a lesser extent the Moon, there have been no surface-based observations of the interior of terrestrial planetary bodies.

Potential Mars Mission Under Consideration

NASA is studying the Mars sample-caching mission for launch in 2018 and also the Mars 2016 Trace Gas Orbiter (TGO) in concert with ESA. NASA and ESA have been working on this since 2007. As a basis for these discussions, in November 2009, the NASA Administrator and the Director General of ESA signed a Statement of Intent for Potential Joint Exploration of Mars *"to consider the establishment of a joint initiative to define and implement their scientific, programmatic, and technological goals for the exploration of Mars. Initially focusing on 2016 and 2018, this initiative would span several launch opportunities with landers and orbiters . . . "*

As currently envisaged, the Mars 2016 and 2018 missions are linked since the 2016 mission is an orbiter that would not only perform atmospheric trace gas science but also provide the space telecommunications relay services to enable communication between mission controllers on Earth and the 2018 rover-cacher. In July 2010, NASA and ESA selected science instruments for the 2016 TGO mission from a joint Announcement of Opportunity. In June 2011, NASA and ESA agreed to explore a single rover for the 2018 mission to accomplish both our science and technology goals. The 2018 mission to put a cacher-rover on the surface of Mars would take advantage of the best energetics (the energy required to transfer mass from the Earth to Mars) in a decade and a half.

Due to increasing budget pressures associated with the nation's fiscal challenges, in June 2011 NASA requested ESA's support for a review of the potential joint Mars program in an effort to maximize available resources, while continuing to meet key scientific and technical requirements of both Agencies. This joint review is currently underway. As part of the ongoing technical review, ESA recently invited the Russian Space Agency, Roscosmos, to consider potential participation in the Mars 2016 and Mars 2018 missions. Russia has yet to formally respond to this invitation.

NASA has had a long and productive history of successful cooperation with ESA, particularly in the area of space science. This relationship has spanned decades. Last month Administrator Bolden and the ESA Director General Dordain met to discuss among other topics the progress of the ongoing Mars exploration program review. At that time they both reaffirmed their Agencies' commitment to explore cooperation on a mutually beneficial Mars exploration program.

Summary

We are in an era of scientific revolution in our understanding of the solar system. The new Planetary Decadal Survey recognizes this scientific revolution and charts an exciting and compelling way forward. To summarize according to the questions posed in your letter of invitation to testify:

1) NASA is studying the implementation of the Mars 2016 and Mars 2018 missions with ESA within available budgetary resources. The Mars 2018 mission would satisfy the objectives of the mission identified by the Decadal Survey as the highest priority flagship mission for the coming decade, subject to the conditions identified above and to funding availability. And it would be the first step towards returning a sample from Mars, which has long been a goal of our larger Mars and planetary exploration strategy.
2) NASA is pursuing a strategic continuum of flyby, orbit, land, rove, and return samples. Ultimately, we plan to return samples from the surface of Mars, both for their scientific value and for the information they will provide in support of what will ultimately be human exploration of the Red Planet. MSL is an integral part of this long-range strategy, both for the entry, descent, landing, and roving technologies it enables and for the scientific contribution it will make to the question of Mars' past and present habitability.
3) NASA and the scientific community have no shortage of compelling and innovative ideas for a robust planetary exploration program, but the fact is that we are in very challenging fiscal times, which requires focus, partnerships, and the development of innovative approaches to reduce the costs of these exciting missions. The Decadal Survey was aware of these constraints and provided multiple concepts for potential flagships, depending on the funding available. Of the recommended flagship missions, we are currently focusing on the Decadal Survey's highest-priority—Mars sample caching—while simultaneously seeking new ways of pursuing the other compelling missions such that they can be realized within the constrained budgets we face. For example, NASA also is currently studying a Jupiter Europa Mission, the Survey's second

priority flagship mission. The Survey's third priority flagship mission is a Uranus Orbiter and Probes mission.

NASA's plans for addressing the Planetary Science Decadal Survey recommendations will be detailed as part of the President's FY 2013 budget request. This is also the time frame in which NASA and ESA will need to have our plans firmly in place in order to implement any proposed Mars 2016 and Mars 2018 missions.

Mr. Chairman and Members of the Subcommittee, I appreciate your continued support of NASA's Planetary Science program. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

Chairman PALAZZO. Thank you, Dr. Green.

I now recognize our next witness, Dr. Steve Squyres, Chair of the Committee on Planetary Science Decadal Survey for the National Academies of Science. Dr. Squyres.

STATEMENTS OF DR. STEVEN SQUYRES, GOLDWIN SMITH PROFESSOR OF ASTRONOMY, CORNELL UNIVERSITY

Dr. SQUYRES. Thank you. Mr. Chairman, Members of the Subcommittee, thank you very much for the opportunity to appear here today.

The National Research Council's decadal recommendations to NASA covered many topics. These include the Planetary Research and Analysis Program, technology development, small Discovery missions and medium-sized New Frontiers missions. In all of these areas, the agency's response so far has been to follow the NRC recommendations closely.

But one area today where NASA has not followed NRC recommendations has been the implementation of large flagship missions. 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 exploration. A program made up of only small- and medium-class missions would be unable to address the most challenging and important issues in planetary science. The decadal report did not state that flagship missions have lower priority than other smaller missions. It stated that an appropriate response to a declining budget is to delay or descope flagship missions, which is a very different thing.

The NRC report provided a prioritized list of planetary flagship missions with clear decision rules for choosing among them. The highest priority flagship mission recommended by the NRC is a Mars sample collection and caching missions to be conducted jointly with ESA, the European Space Agency. This mission would collect a well-chosen suite of samples for return to Earth at a later date. Sample return is the crucial next step in Mars exploration and is the best way of addressing the question of whether life ever took hold on Mars. The mission would also conduct significant new science on the Martian surface.

Other high-priority flagship missions discussed in the report included a mission to investigate a probable subsurface ocean of liquid water on Jupiter's moon Europa and an orbiter probe mission to the ice giant planet Uranus.

As the spectacularly successful Cassini-Huygens missions to Saturn and Titan has 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. The same may also be true for high-priority flagships as well.

ESA can bring substantial capabilities and resources to a partnership, lessening both the risk and the financial burden to NASA. In my view, the publicly available budget guidelines that have been provided to NASA by the Office of Management and Budget are sufficient as they stand to allow the agency to enter into a partnership with ESA and to carry out the program recommended by the NRC. To date, however, the Administration has not committed to this partnership.

If no such commitment to a flagship mission is made, the result will be highly detrimental to the future of U.S. planetary science. Speaking more pragmatically, I fear that an inability to enter into a mutually beneficial partnership with a willing, eager and highly capable agency like ESA may jeopardize future international partnerships as well.

Three other points are noteworthy regarding the recommended Mars mission specifically. First, NASA's current concept is substantially descoped from the original one, exactly in line with the decadal recommendation to descope flagship missions in the face of declining budgets. Second, the current concept makes extensive use of existing hardware designs, reducing cost risk. Third, the remaining missions in the sample return campaign can be carried out over an extended period of time, if necessary, spreading the cost out in time as well.

Finally, I would like to stress a critical point. The ability to carry out the most challenging tasks in deep space exploration, tasks like landing a rover on Mars or orbiting Europa, is one of our Nation's great 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. So 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 the willingness to commit these resources for this essential task.

Thank you.

[The prepared statement of Dr. Squyres follows:]

PREPARED STATEMENT OF DR. STEVEN W. SQUYRES, GOLDWIN SMITH PROFESSOR OF ASTRONOMY, CORNELL UNIVERSITY

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 bil-

lion. 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 descoped 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.

Chairman PALAZZO. Thank you, Dr. Squyres.

I thank the panel for their testimony, reminding Members that Committee rules limit questioning to five minutes. The Chair will at this point open the round of questions. The Chair recognizes himself for five minutes.

Dr. Green, how does restructuring the James Webb Space Telescope program and the increased funds needed to complete the program affect NASA's Planetary Science Division? Will there be programs cancelled as well?

Dr. GREEN. The Administration has stated clearly that James Webb is a priority and that the funding for James Webb in the future based on its shortfall in the existing budget based on the President's 2012 submission to Congress would be handled in a 50/50 arrangement between the Science Mission Directorate and other elements within NASA. In addition to that, OMB has been working with the Science Mission Directorate to determine the process and procedure to identify those funds and once that has been completed, and it is not, it will be delivered to Congress in February when the President delivers his 2013 budget.

Chairman PALAZZO. How are you executing the programs in the Planetary Science Division knowing that there will be likely cuts to those programs nearly halfway through next year, or the current fiscal year?

Dr. GREEN. Well, currently, as we create through our partnership with ESA and discussions on how to implement Mars 2016 and the Mars 2018 mission, we have entered those discussions knowing that there may be changes or possibly changes in our current budget profile. So we have considerable action with ESA. We have not made commitments that would by the Administration commit them to that set of missions and so we have done so in good faith that by the time the President has determined his priorities, delivered his budget to Congress in February, our path forward will be clear.

Chairman PALAZZO. Dr. Squyres, there is a widely held perception that NASA is no longer in charge of developing its programs and is instead being directed by the OMB on which programs to pursue. What is the danger to U.S. scientific leadership and to the scientific community as a whole if this is indeed the case? And does this undermine the legitimate work of the decadal survey process?

Dr. SQUYRES. The danger to planetary science in the United States is severe if that is the case. As I stressed in my opening remarks, flagship missions are an essential part of a balanced program of exploration. We rely on flagship missions to do the most important science, and if we are not able to implement those missions, then our leadership in areas like answering fundamental questions like was there ever life on Mars, is there life on Europa, these really important questions, is going to be, I won't say challenged, it is going to go away. We are going to lose a fundamental capability. And moreover, not only do we lose the science but we cannot simply give up that technical capability, the ability that we have to do things like orbiting Europa or landing a rover on Mars. That is something that we know how to do in this Nation, and if we give that capability up, the people who know how to do that, they are going to go off to other jobs, they are going to do other things. These are smart people who are in demand and you simply cannot reconstruct that instantly. So I feel that the danger is severe both to the science that we have identified in the NRC report now but also to our prospects for being able to do similar science in the future.

Chairman PALAZZO. Why do you say NASA is no longer working toward flagship missions?

Dr. SQUYRES. I am perplexed, sir. I sense within the agency a strong desire to do flagship missions, and my reason for saying that is that I know that in response to the NRC's report, NASA has totally restructured the partnership with ESA for the Mars mission to make it much more affordable, affordable within budget guidelines. They have done exactly as Jim Green said and they have found ways to—they are working on ways to dramatically decrease the size and cost and complexity of the Europa mission. So the studies are going forward. The designs and the missions are being revamped so that the decadal recommendations can be followed and yet there is no commitment being made. I am perplexed.

Chairman PALAZZO. Dr. Green, would you like to comment?

Dr. GREEN. Yes, I would. Of course, we all know our roles and responsibilities within the Federal Government. OMB, is role, of course, is one of developing budget with OSTP's use of the President's priorities and then implementing that through interactions with the agencies and moving forward. My role within the Federal Government is to advocate for planetary science. I am the top official for the advocate for planetary science as we move forward. We recognize in this environment a difficult budget situation that we are in that compromises have to be made, decisions have to be executed that are based on the Administration's priority. Currently, OMB has not officially notified NASA of canceling Mars 2016 or 2018. And so those discussions are ongoing. We meet with OMB on a regular basis. They know the details of our studies. We have worked with them quite intimately and of course we are eagerly awaiting what the ultimate priorities will be and whether we will be able to proceed with the Mars 2016 and 2018 mission as our partnership with ESA has delineated.

Chairman PALAZZO. Thank you.

I now recognize our Ranking Member, Ms. Edwards from Maryland.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to both of our witnesses, and Dr. Green, I have to tell you, when I hear your testimony and I see you, what I see is a person of science who has real enthusiasm for the work that you are doing. It actually radiates, and so you have given me that energy too, and so thank you.

I want to get right to it. First of all, Dr. Green, did OMB review the testimony that you are giving to this Subcommittee today?

Dr. GREEN. Yes, OMB as our normal procedure does review our written testimony.

Ms. EDWARDS. And did they have to approve it before you could submit it to the Subcommittee?

Dr. GREEN. Yes, that is the normal process.

Ms. EDWARDS. And Dr. Green, Dr. Squyres testified that the National Academies has deemed the joint NASA/ESA Mars sample collection and caching mission to be the highest priority flagship mission in planetary science, and I appreciate Dr. Squyres' testimony about the importance of balance within the mission directorate. Yet according to Dr. Squyres, and I quote, "To date, however, the Administration has not committed to this partnership." Is

Dr. Squyres correct in saying that the Administration has not yet committed to the NASA/ESA mission?

Dr. GREEN. As I mentioned earlier, we have not been notified by OMB that Mars 2016 or 2018 has been cancelled. Therefore, our approach is to continue to work with ESA, continue to find ways to lower our costs and meet both of the objectives from European Space Agency and for NASA.

Ms. EDWARDS. But have you gotten an explicit commitment from the Administration on the NASA/ESA partnership?

Dr. GREEN. Based on the fact that OMB has not cancelled officially the 2016 and 2018 mission, which is part of our Statement of Intent that Administrator Bolden and Director General Dordain signed in 2009, we are proceeding on good faith in our connections with ESA and continuing to plan this mission.

Ms. EDWARDS. But not because you have gotten an explicit commitment from the Administration?

Dr. GREEN. We believe that because we have a signed amendment, a Statement of Intent to proceed on these studies, that we will continue to do so.

Ms. EDWARDS. Dr. Squyres, do you believe that there is an explicit commitment on behalf of the Administration for the NASA/ESA mission?

Dr. SQUYRES. I have had the opportunity to engage in conversation with individuals at the Office of Management and Budget, and in those conversations, I have been told the Administration is at this current time not ready to make such a commitment.

Ms. EDWARDS. Okay. And so Dr. Green, does NASA want to do the mission?

Dr. GREEN. NASA does want to do this mission.

Ms. EDWARDS. Does ESA want to do the mission?

Dr. GREEN. ESA does want to do this mission, and in fact, we need each other more than ever before.

Let me comment and take this time to talk a little bit about that relationship because it is extremely important to understand. In the past, our connections with a European partner or another agency have always been who leads the mission, and one mission at a time. The particular effort that we are engaging with ESA is for a series of missions, and instead of a small contribution, it is a major contribution on each other's part. So this is a long-term partnership that we are moving forward with and we have the agreement by Director General Dordain of ESA and Administrator Bolden to continue aggressively to pursue our programs. So indeed, NASA is fully behind the 2016 and 2018 mission.

Ms. EDWARDS. So let me just be clear. The scientists at NASA want to do the mission?

Dr. GREEN. Yes.

Ms. EDWARDS. At ESA, they want to do the mission?

Dr. GREEN. Yes.

Ms. EDWARDS. Congress hasn't prohibited it.

Dr. GREEN. Yes.

Ms. EDWARDS. So who is blocking the two agencies from moving forward?

Dr. GREEN. As I had mentioned earlier, OMB takes their job seriously of looking throughout the Federal Government for opportuni-

ties to overall lower the costs to this Nation, the taxpayers, and consequently, they are using a system of priorities to be able to look at these programs to decide which will move forward and which will be cancelled.

Ms. EDWARDS. You know what, Dr. Green? I don't want to put you in the position of having to answer that question. What I want to know and it would be helpful to hear from OMB directly about why things are being held up and who is holding them up, given that the two agencies that would be principally responsible for moving this forward at the recommendation in the decadal survey as we have heard from Dr. Squyres why we are sitting in a holding pattern. And so I look forward to hearing from OMB about that.

And Dr. Squyres, just as I finish here, I just want to be clear. Is there anybody in particular at OMB who told you about the Administration's willingness or unwillingness to commit to the partnership with ESA?

Dr. SQUYRES. Yes, it was a meeting with Sally Ericsson.

Ms. EDWARDS. Thank you.

Chairman PALAZZO. I now recognize the gentleman from Texas, Mr. Smith.

Mr. SMITH. Thank you, Mr. Chairman.

Dr. Green and Dr. Squyres, in the last 20 years or so, the search for extraterrestrial intelligence has become, I think, a serious academic and scientific subject. How do you feel that the National Academies of Science think about the likelihood of microlife being found in our own solar system? Dr. Green, let us start with you and then go to Dr. Squyres.

Dr. GREEN. One of the aspects of planetary science is in the area of astrobiology—what we have been doing is looking at, does life live in extreme places on this planet, and in many of these extreme places, we do find life.

Mr. SMITH. Actually, you are anticipating my next question, but let me go back to that first one again. National Academies of Science, do they think there is a strong likelihood of life being found in our solar system?

Dr. GREEN. The National Academy through the planetary decadal has a major undercurrent of astrobiology science that is in it. It is indeed all about looking at regions in the solar system with the potential of habitability and the potential of life. So yes, indeed, it does.

Mr. SMITH. And now my next question that you anticipated, again to ask both of you, and actually, Dr. Squyres mentioned it a while ago, the possibility of life being found on Mars or Europa and right before this hearing today you were saying to me that if we just find a thimbleful of water, it is very likely that that is going to contain some form of life. So do you think or do you want to say today that it is almost certain that we will find microlife on Mars and Europa? Dr. Squyres.

Dr. SQUYRES. Sir, I learned a long time ago, about eight years, when we first landed our rovers on Mars, not to predict.

Mr. SMITH. I know where you are going and therefore give me a percentage of likelihood.

Dr. SQUYRES. You know, if I could do that, sir, I would be so——

Mr. SMITH. If you say 100 percent, you will make a lot of news today.

Dr. SQUYRES. Yeah, I would be thrilled. What I would like to say is that it is no coincidence that the two highest priority planetary flagship missions recommended were to Mars and Europa. What sets those worlds apart is their potential for life, and it is the judgment of the National Academy of Sciences and National Research Council that the probability is high enough that there could be life on those worlds or could have been life on those worlds that it is worth investing the resources in those flagship missions.

Dr. GREEN. Dr. Squyres, let me use a legal term. Is it more likely than not we will find life on Mars and Europa, or one or the other if you think it is more likely than one.

Dr. SQUYRES. I simply don't know, and that is the nature of science, sir.

Mr. SMITH. Okay. Dr. Green?

Dr. GREEN. I would agree with everything Steve said.

Mr. SMITH. You are not going to bite at "more likely than not"?

Dr. GREEN. If we don't have the opportunity to look, we will never know.

Mr. SMITH. Okay. Fair enough. Let me on my next question to both—actually, Dr. Green, I am going to pass on you. I don't want to put you on the spot either, but let me direct my next question to Dr. Squyres, and it is a follow-up to the Chairman's question a while ago about OMB. OMB is clearly saying that they feel there is not enough money for all the planetary missions, and clearly they are, I think, picking and choosing what they consider to be the Administration's priorities. My question, Dr. Squyres, is this. Do you think the Administration's priorities are the general consensus priorities of the scientific community?

Dr. SQUYRES. The general——

Mr. SMITH. And if not, where do they differ?

Dr. SQUYRES. The general consensus priorities of the science community are, I believe, those expressed in the decadal report. So to the extent that the Administration's position differs, than it differs from the scientific consensus.

Mr. SMITH. Okay. What would be examples of that?

Dr. SQUYRES. Examples of that would be an unwillingness to commit to these high-priority flagship missions despite the fact that NASA has labored heroically and I believe successfully to bring their costs into the affordable range, indeed, into the range of budget projections that have been provided publicly by OMB. So it is a little bit perplexing when you see OMB's budget projections, which by the way are declining precipitously for planetary exploration, which is another issue for this Committee to consider. But even given that, the missions that NASA has now restructured in response to the decadal survey fit within the projected budget profiles and yet the agency has not been given the opportunity to move forward with those anyway.

Mr. SMITH. Okay. Thank you, Dr. Squyres. Thank you, Dr. Green.

Thank you, Mr. Chairman.

Chairman PALAZZO. Ms. Fudge, I understand you don't have any questions at this time?

Ms. FUDGE. That is correct.

Chairman PALAZZO. So at this time the Chair recognizes Mr. Rohrabacher from California.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

Dr. Green, what was the original budget estimates that we approved of for the James Webb telescope?

Dr. GREEN. Because that is not in my direct field nor am I involved in any of the budget determinations of James Webb, I will have to get back to you.

Mr. ROHRABACHER. Dr. Squyres, do you know that?

Dr. SQUYRES. No, sir, I do not.

Mr. ROHRABACHER. Let me remind you, it was $1.6 billion, and I suppose you don't know how much today we are being asked to complete the program.

Dr. GREEN. I believe the James Webb group has completed their initial, or their review of a re-plan and have provided to Congress that cost estimate.

Mr. ROHRABACHER. Right. That is $8.8 billion. I would suggest to you there is a relationship between that cost overrun and the other cost overrun that we have to deal with here in Congress, and the success of America's space programs. Would you agree with that?

Dr. GREEN. Well, what I try to do within the Planetary Science Division is to articulate our goals and our priorities and let the Administration determine its overall priority.

Mr. ROHRABACHER. I would suggest that the people of NASA decide to get involved when certain elements of their operation and other people within the space program are doing things that are detrimental to the long-term interests of a well-funded and effective space program. If there is anything that is a greater danger, I would say that cost overrides of this nature are certainly a greater threat to a viable space program than the asteroid belt or anything else that you would face up there that God has presented an obstacle for us to moving forward into space. This is outrageous.

So you have $1.6 billion for the James Webb telescope, now it is $8.8 billion. Would you think that perhaps the space launch system at $18 billion now as an estimate might go up with the same magnitude of an increase in cost? I won't be burdening you both because obviously you don't know that, it is not your area, but let me—Mr. Chairman, we need to put on notice NASA and the rest of these people, these kind of cost overruns are killing the program, and I certainly appreciate the great words that you said and I have been a supporter of the space exploration program. I think it is a gem, an incredible thing that we can brag about and be proud about as Americans. What we can't be proud about is this bureaucratic incompetence that is leading to such massive billion-dollar expenditures that are coming right out of the heart of these programs. We have got to get serious about this, and if we are not, it is not—by the way, I don't believe it is Congressional back and forth and indecision that is causing these things. I don't believe that. I believe that we have honestly set forth some money for programs and we come back all the time with cost overruns that kill our ability to do any other programs.

Well, I hope that we can send our exploration missions to Mars and to Europa. I think you are right: that is a noble and an historic

endeavor and should be led by the United States of America. We might end up having to do cooperation with our European friends or maybe even the Russians in order to accomplish these because of these damn cost overruns. Well, I would hope that people realize you have a right to criticize other people within the American space program when they are doing these things that are going to end up with such a horrible outcome for all of us.

Let me get back to the space launch program, are any of these missions we are talking about, landing these things on Mars, the rovers and the various Mars programs and Europa. Except for a manned mission, is there some reason we need the megarocket of all times, the space, they call it gigantic or what—the space Titanic that we are building which will have its own cost overruns as the iceberg in the way. Do we need that extra-huge rocket to accomplish any of the missions you are talking about today?

Dr. GREEN. Currently, the design of our 2016 and 2018 missions in cooperation with ESA will use the EELVs, the expendable launch vehicles, that we currently have under contract through the NLS–2 contract.

Mr. ROHRABACHER. So if we end up with a cost overrun which is now $18 billion at the same level as the cost overrun as the James Webb telescope, it will suck up all the money from all these various programs and we don't even need that rocket in order to accomplish the missions that you are telling us are so important today. I agree with you. Thank you very much.

Chairman PALAZZO. I now recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

Radioisotope power systems utilize heat converted from the nuclear decay of radioactive isotopes to generate electricity. RPSs, as they are commonly known, are frequently used to power spacecraft that travel large distances and in extreme environments, yet the United States ended production of plutonium-238, the key nuclear component of RPSs, back in 1988. Despite no new production, its use continues. Most recently, the Mars Science Laboratory used about 3.5 kilograms for the multi-mission radioisotope thermoelectric generator and the next Discovery mission has reserved 1.8 kilograms for two advanced sterling radioisotope generators. The decadal survey indicates that in order to complete the recommended program, new plutonium-238 production is essential or more deliveries from Russia will be necessary. It concluded, and I quote, "The committee is alarmed at the status of plutonium-238 availability for planetary exploration. Without a restart of plutonium-238 production, it will be impossible for the United States or any other country to conduct certain important types of planetary missions after this decade."

Dr. Green, what programs are in jeopardy if production does not get underway for plutonium-238?

Dr. GREEN. Mr. Brooks, as you know, Congress actually has been quite generous in allowing us to have the funding necessary to work with the Department of Energy to move forward in developing the plans necessary to restart the production of plutonium-238 that as you point out so well is vital to many of our missions in the future. We feel confident that as we move forward in this

budgetary process and as our relationships with Department of Energy are quite excellent that we will begin to do that development of the capability that then will generate the fuel necessary for the future. So I believe we are on the path to do that, and once again I want to thank Congress for recognizing that and enabling us to facilitate that.

Mr. BROOKS. Well, the House Appropriations Subcommittee for Energy and Water denied funding for DOE for plutonium-238, but back to my question. What programs are in jeopardy if production does not get underway?

Dr. GREEN. We do have a limited supply of plutonium-238 in the Department of Energy and so consequently that will be used for potential missions such as, as you mentioned, our Discovery mission. We are using plutonium-238 for the Mars Science Laboratory right now. There is a lot of discussion based on what the 2018 mission will look like and where it needs to go, whether plutonium-238 will be needed for that.

Our Discovery program and our New Horizons, or New Frontiers program and many of its missions all require plutonium-238 to be able to be accomplished. So indeed, many of the missions throughout the planetary decadal—and this is one of the reasons why they are recommending the ability to produce this vital material will be in jeopardy if we are not able to do that by the end of this decade.

Mr. BROOKS. Thank you, Dr. Green. Now, further, how long does it take from the instance we decide to restart production before we have available plutonium-238? Do you have a judgment on that?

Dr. GREEN. We delivered a cost-sharing plan that also outlines some of the basic capabilities to Congress more than a year ago, and following that plan, let me just mention a couple aspects of it. Currently, our need for plutonium is such that existing capabilities within the Department of Energy can be utilized. This means that no new facilities have to be developed but only a time-sharing of the current use of those facilities. So depending upon the environmental assessment impacts and other studies that need to be done to then delineate how we would move forward, production could begin within the next couple years.

Mr. BROOKS. In your judgment, when is the absolute deadline for production to begin before it starts adversely affecting some of our NASA missions?

Dr. GREEN. If we stay on the time scale as I mentioned, we should be okay.

Mr. BROOKS. Well, do you have a judgment as to what that time frame is? How long?

Dr. GREEN. We would like to see the production of plutonium-238 begin within the next several years, and once that material is produced, there is quite a process—set of processes that have to kick in to be able to make that available for future missions and so there is a long lead time that we have to be cognizant of.

Mr. BROOKS. And finally, do you have a judgment as to the cost to restart plutonium-238 production?

Dr. GREEN. As delineated in that report, utilizing the existing facilities in the Department of Energy, that cost estimate is anywhere between $70 and perhaps $90 million.

Mr. BROOKS. Thank you, Dr. Green.

Chairman PALAZZO. Mr. Clarke, welcome to the hearing. I understand you don't have any questions at this time? Okay.

I now recognize the gentlewoman from Florida, Ms. Adams.

Mrs. ADAMS. Thank you, Mr. Chair.

Dr. Green, there have been several reports in the media recently that NASA is considering abandoning the flagship Mars sample and caching mission due to specific direction from OMB. Do you believe Mars missions to study atmospheric as well as geophysical conditions are a crucial step for planning a human exploration to Mars, something for which SLS could be used?

Dr. GREEN. Indeed, I believe that as the National Academy has stated in other reports, sample return is absolutely vital before we provide missions and plan missions for humans to explore Mars.

Mrs. ADAMS. Do you believe, could the United States send humans to Mars safely without this type of scientific inquiry beforehand?

Dr. GREEN. Based on the decadal survey and what we know about Mars, I do believe it is essential that we bring back samples.

Mrs. ADAMS. So what role does the cost of launching these missions play into your budget profile? For example, would it be possible for NASA to build a satellite or a rover that you did not have the money to launch it on time?

Dr. GREEN. I am sorry. Could you please restate that?

Mrs. ADAMS. What role does the cost of launching these missions play into your budget profile? For example, would it be possible for NASA to build a satellite or a rover that you did not have the money to launch on time?

Dr. GREEN. Indeed, before we can move forward with any mission, we have to be able to plan adequately for all aspects of the mission, so that is our best guess in terms of what it would cost to develop such a mission along with its science and instruments, but in addition to that, we also have to budget for a launch vehicle, and how we do that is, we use the current contract that NASA has. It is called the NLS–2 contract. Based on the mass of the spacecraft and other engineering aspects of that——

Mrs. ADAMS. Just yes or no at this point, because I have some other questions.

Dr. GREEN. Yes, we have to be able to budget for the launch vehicle within our budget.

Mrs. ADAMS. Thank you.

Dr. Squyres, let us assume the Administration does not allow the Mars partnership with ESA to move forward and the ESA does the mission with Roscosmos? What would be the effect on American planetary science if European and Russian scientists having access to Martian soil and rock samples that Americans do not?

Dr. SQUYRES. I think there are two detrimental effects. One, of course, is that science in this Nation would suffer because we would no longer have the ability to do the cutting-edge science because the cutting-edge science requires access to materials that we would not have. The other is that having lost the capability to fly such missions, we would be poorly positioned to develop other important science missions beyond that, so I think we would lose two ways.

Mrs. ADAMS. You state in your written testimony that you believe the publicly available budget guidelines given to NASA by OMB are sufficient to allow Mars sample collection if we partner with ESA. If the budget profile is sufficient, the skill sets are available and the partner is willing, what is stopping the mission from moving forward?

Dr. SQUYRES. In my view, it has been the unwillingness to date of the Administration to commit to that partnership.

Mrs. ADAMS. And there is a widely held perception that NASA is no longer in charge of developing its missions and it is instead being directed by OMB on which missions to pursue. What is the danger to U.S. scientific leadership and to the scientific community as a whole if this indeed is the case? Does this undermine the legitimate work of the decadal survey process?

Dr. SQUYRES. The decadal survey was our best attempt as a community of planetary scientists to state priorities for space exploration. It was carried out at the request of NASA. We gave them our best considered advice as a community of literally thousands of planetary scientists and it is important to us to either see that advice followed or to understand why it has not been.

Mrs. ADAMS. What is the danger to U.S. scientific leadership and the scientific community as a whole?

Dr. SQUYRES. The danger to our leadership is that we could lose it, flat out. We have a capability as a Nation to do deep space exploration that no other entity on this planet possesses. We are better at this than anybody. And I would like to see this Nation maintain that capability not just for the science of these missions but for the utility that that capability has to conduct other missions in the future that we can't even conceive of at this time.

Mrs. ADAMS. And just to be clear, Dr. Green, you said that OMB is the President's priority basically, correct?

Dr. GREEN. Well, the President——

Mrs. ADAMS. Yes or no.

Dr. GREEN. Yes.

Mrs. ADAMS. Thank you.

I yield back.

Chairman PALAZZO. At this time we will go into a second round of questions for any Members that would like to ask additional questions, and I will go ahead and recognize myself first.

Dr. Squyres, or Dr. Squyres, in your dealings with our international partners, most notably, the European Space Agency, do you sense frustration with the United States or a growing unwillingness to partner with us in the future?

Dr. SQUYRES. I hope, sir, that there is not a growing unwillingness, and no, I have not sensed a growing unwillingness. In fact, I have sensed exactly the opposite, that there is an enthusiasm to future partnerships. It has not been my perception in talking to my European colleagues that they have concluded yet that we are an unreliable partner. I sense enthusiasm. I do sort of sense frustration.

Chairman PALAZZO. What is the scientific rationale for a Mars sample return mission, and why is this deemed as the most important flagship mission for the coming decade?

Dr. SQUYRES. I was hoping somebody would ask that. Mars sample return is, in the view of our community, and the next logical step in Mars exploration. If you look at what we have accomplished at Mars in the last 15 to 20 years, we are now to the point where the most significant step forward can come from bringing samples back. The reason for that is that, it is twofold. First of all, we have learned enough about Mars to know the kinds of places we must go to get the most important samples so we are ready. The other thing, and this is coming from somebody who has devoted his career to building instruments and sending them to Mars is that the best science is always going to get done in laboratories on Earth. The kind of instrumentation that exists in laboratories on Earth far surpasses in its capability what you could ever hope to send to the Martian surface on a robotic vehicle.

Moreover, it is important to recognize that return samples are in a sense a gift that keeps on giving. The very best science ever done with samples collected from the moon during the Apollo program 40-plus years ago is being done today by scientists who had not been born at the time those samples were collected using instruments that had not been conceived of. So if you can bring samples back, they not only enable you to do cutting-edge science today but they enable you to do it for potentially decades into the future.

Chairman PALAZZO. I now recognize our Ranking Member, Ms. Fudge from Ohio.

Ms. FUDGE. Thank you, Mr. Chairman.

Both of these questions will be to both or either, but preferably both. Thank you for coming. With the prospects of flat or reduced budgets for planetary sciences, NASA will be challenged to initiate expensive flagship missions while also maintaining a balanced program that includes small- and medium-sized missions. To both of our panelists, our witnesses, what are the options for pursuing top-priority flagship planetary missions and how should Congress weigh in on those options?

Dr. GREEN. For us to be able in the planetary budget, which is declining, that the President submitted to Congress in February, indeed, that is very challenging, and for us to be able to pull off the decadal recommendations of a balanced portfolio with small, medium and large flagship missions, we have to be able to partner, and with ESA we have found an outstanding partner. They have been fabulous throughout our entire connections over the years and we have done a number of major things together, and this partnership is very strong.

Ms. FUDGE. Thank you.

Dr. SQUYRES. The only thing that I would add to Dr. Green's statement is that I would like personally to commend the agency on the work that they have done along these lines already. When we wrote the decadal report, we identified the need to dramatically reduce the scope, cost and complexity of both the Mars and Europa missions, and NASA has already taken substantial strides forward in doing both of those.

Ms. FUDGE. Thank you.

To what extent is NASA's Robotic Planetary Science program an enabler for human exploration missions beyond low Earth orbit?

Dr. GREEN. You know, while humans are developing the capability to leave low Earth orbit, this is really the decade for planetary scientists. In other words, the President's agenda for which he has a flexible path, a number of destinations, we are there discovering a variety of aspects of that phenomenon looking at the hazards, understanding what those environments are all about. That is absolutely essential. You know, human exploration is not Star Trek. It is not go where no man has gone before. It really involves detailed studies of a variety of objects that human exploration is planning to go to such as back to the moon, asteroids, and of course, Mars. So this is a perfect time for us to be able to really get down to business and do a tremendous amount of science in support of human exploration also.

Dr. SQUYRES. Yeah, I will just add that one of the things that we stressed in the decadal report was the way in which these missions to targets that are potential targets for human exploration can lay the groundwork for that, and this is something NASA has done since almost the beginning of the agency. I teach a course at Cornell about the history of exploration, and I was just talking to my class the other day about the way that the Apollo landings on the moon were preceded by the Ranger missions and the Surveyor missions and the lunar orbiter missions and all of those missions laid the groundwork that was partially enabling for the success of Apollo. I think the same can happen at asteroids. I think the same can happen at Mars.

Ms. FUDGE. Thank you, gentlemen.

Mr. Chairman, I yield back.

Chairman PALAZZO. Seeing no other Members with additional questions, we will bring this hearing to a close. I thank the witnesses for their valuable testimony and the Members for their questions. The Members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments from Members.

The witnesses are excused and this hearing is adjourned.

[Whereupon, at 11:13 a.m., the subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Jim Green,
Planetary Science Division Director,
Science Mission Directorate,
National Aeronautics and Space Administration

From Chairman Stephen Palazzo

1) Your testimony cites the importance of a balanced program, and included in such a program is the Research & Analysis (R&A) component. It is this program where discoveries are generated, where analysis is conducted, and where opportunities to train our future scientists begin. Is the R&A account being unjustly raided to pay for the more visible programs, such as flagships? How do you recommend preserving the vital balance among different sized programs given current budgetary constraints?

Response: The National Research Council's (NRC) 2011 Decadal Survey for Planetary Science (*Vision and Voyages for Planetary Science in the Decade 2013-2022*) addresses the appropriate balance for Research and Analysis (R&A) funding. The NRC's Decadal Survey recommends that "NASA increase the research and analysis budget for planetary science by 5 percent above the total finally approved FY 2011 expenditures in the first year of the coming decade, and increase the budget by 1.5 percent above the inflation level for each successive year of the decade." The Decadal goes on to say that even if the budget picture turns out to be less favorable than the committee assumed, "high priority should be placed on preserving funding for research". NASA therefore recognizes the importance of research in the recommendations of the Decadal and plans to work with the scientific community – through the NASA Advisory Council, for example – to implement a balanced program of research and flight investigations.

2) In the question and answer session during the hearing, you mentioned that the timeline to restart production of plutonium-238 could begin within a few years. You then explained that once material is produced, that there exists "quite a process" that would be necessary to be able to use plutonium-238 in future missions and that there would be a long lead time. Can you explain the processes that need to be met in order to utilize plutonium-238 once it is produced? Can you provide us with a more detailed timeline from receipt of appropriate funding, to production, to use? Please also indicate the projected needs vice available resources NASA has for plutonium-238 (in kilograms).

Response: These questions are in large part similar to those answered in reports issued to in response to both the 2010 Energy and Water Development Appropriations Bill for Fiscal-Year 2010 (ref. A) and the NASA Authorization Act of 2010 (ref. B). Both reports were jointly drafted by NASA and DOE and submitted by the requested agency to Congress. These references are still directly applicable to the current questions posed.
References:

A. "Start-up Plan for Plutonium-238 Production for Radioisotope Power Systems", Report to Congress, June 2010

B. Report Regarding Restart and Sustainment of U.S. Plutonium-238 Production Capability – A Joint NASA-DOE Approach, Pursuant to Section 806(c) of the NASA Authorization Act of 2010 (P.L. 111-267), August 2011

Detailed Responses:

a. Can you explain the processes that need to be met in order to utilize plutonium-238 once it is produced?

Response: Section IV (ref. A) defines the three basic steps required to produce Pu-238. They are target fabrication, target irradiation and post-irradiation target processing. After targets are irradiated, additional cooling time is required before they are processed to allow impurities introduced in the irradiation process to decay. Irradiated targets will be processed to extract Pu−238. From this step, newly produced Pu−238 is available for fabricating heat sources and power systems in existing operating infrastructure that is not part of the scope of the restart project. Those steps involve shipping Pu−238 to Los Alamos National Laboratory for storage until it is used to fabricate sealed heat sources for NASA. Sealed heat sources are shipped to Idaho National Laboratory for power system assembly and testing and delivery to the customer. The duration of these activities depends on the number and type of power systems to be provided for a mission and typically spans three to five years or longer for a major flagship mission.

b. Can you provide us with a more detailed timeline from receipt of appropriate funding, to production, to use?

Response: An excerpt from Section 2.0, (ref. B), provided below, identifies the currently anticipated schedule inputs available. NASA has provided DOE funding to initiate the evaluation of alternatives; subsequent planning will be conducted leading to a more robust schedule approximately one year after a formal project start.

> "In response to the Section 806(c) request for an anticipated schedule, only a notional schedule to reestablish a domestic Pu-238 production capability can be developed by DOE at this time, based solely on the plan reported to Congress in June 2010. The plan is based on expert knowledge of potential approaches required to reach a targeted production rate of 1.5 kg/year, and is recognized to be an initial plan subject to further modification during project and budget formulation. Corresponding to information previously published, it assumes the use of existing, operating isotope production facilities at Oak Ridge National Laboratory for processing irradiated targets. The project will be executed in accordance with DOE's formal process for evaluating and implementing capital acquisition projects, which includes a formal evaluation of alternatives and the establishment of updated cost and schedule estimates to support project decisions during the formulation process. Once this evaluation and updates are developed and decisions are made, which could be approximately one year after project start, a more robust schedule would be available. DOE and NASA have agreed to proceed to this formal project milestone, pending resolution of each agency's appropriation for this project in Congress."

The establishment of a Pu-238 production capability is only the first step to final use as a power source. The timeline leading to a mission's use of the produced plutonium is outlined in the response to question a. above.

c. Please also indicate the projected needs vice available resources NASA has for plutonium-238 (in kilograms).

Response: Referring to reference B, section 4.0, the anticipated needs are mission dependent, and based on current mission planning forecasts. The relevant section in reference B, section 4.0 is is reproduced below. The projected needs for Pu-238 will be updated as future mission plans are updated.

4.0 Mission Applications

NASA has identified a continued need for radioisotope power systems in fulfillment of the agency's robotic planetary mission objectives as determined by agency leaders using advisory input gathered from the broad scientific community. These needs are formally assessed as part of the institutionalized NASA mission-forecasting process known as the Agency Mission Planning Manifest (AMPM). The AMPM identifies possible RPS missions. NASA transmits these forecast updates to DOE on a regular basis. The most recent update was provided in March 2010. While its recommendations are not yet incorporated, the recently released Decadal Survey report will have a strong influence on the next release of the AMPM and its identification of the potential Pu-238 mission set.

The joint DOE-NASA implementation approach outlined above would support the following NASA mission applications identified in the most recent AMPM:

	Power Requirement (We)	Pu-238 Usage (Kg)
Missions scheduled for launch in 2010-2014		
Mars Science Laboratory†	100	3.5*
Missions envisioned for launch in 2015-2019**		
Discovery 12	280	1.8
Mars (radioisotope power systems and heater units)	280	1.8
Missions envisioned for launch in 2020-2024		
Major Outer Planets Mission†	612	21.3
Discovery 14	280	1.8
New Frontiers 4	280	1.8
Missions envisioned for launch in 2025-2030		
New Frontiers 5	280	1.8
Discovery 16	280	1.8

Notes:

† Mars Science Laboratory is designed to use the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) technology and the Major Outer Planets Mission is currently baselined to use MMRTGs. Any changes in approach recommended by the Decadal Survey have not yet been incorporated; however the report reaffirms the need for new Pu-238 production. The rest of these RPS-enabled missions assume the use of Advanced Stirling Radioisotope Generator technology, reducing the quantity of Pu-238 required by a factor of four to meet these power requirements.

* Plutonium for the Mars Science Laboratory MMRTG has been allocated from available inventory. The MSL MMRTG, including the Pu-238 fuel, is ready for flight in November 2011. *{Note, the MSL and its MMRTG have successfully been launched on November 26, 2011.}*

** In contrast to the mission application set identified in the June 2010 "Start-up Plan..." report, the Lunar Precursor mission supporting NASA's Exploration Systems mission needs has been dropped from the 2015-2019 planning set pending further study.

3) Can NASA meet its mission objectives for Mars 2018 without flying Mars 2016?

NASA is continuing to assess the plan for future missions within the Mars Exploration program. NASA could meet its objective for the potential Mars 2018 mission without flying the Mars 2016 mission. However, doing so would entail accepting the risk that the Mars 2018 mission would rely on older U.S. science orbiters (2005 Mars Reconnaissance Orbiter and 2013 MAVEN) for high data rate transmission between Earth and the 2018 rover on the surface of Mars. If NASA does not participate in the proposed Mars 2016 mission, the European contributions to the proposed 2018 mission could be at risk and subject to re-negotiation, or re-consideration within Europe.

From Acting Ranking Member Jerry Costello

1) How important are the strategic capabilities, scientific knowledge, and technical expertise that the U.S. has gained through Mars exploration and other planetary science missions to NASA's future plans for solar system exploration and human exploration beyond low-Earth orbit?

Response: Strategic capabilities, technical expertise, and scientific knowledge gained by NASA's Planetary Science Division (PSD) mission activities in exploring various portions of the solar system are absolutely essential for the success of human exploration as they go beyond low Earth orbit. Over the past few decades and especially over the past fifteen years, NASA has successfully delivered orbiters, landers, and rovers to Mars, and from these, has gained both the scientific and engineering knowledge essential for future exploration activities. NASA is the only organization in the world that has gained the expertise to safely land and rove on the surface of Mars. With the Mars Science Laboratory, launched on November 25, 2011, NASA is demonstrating completely new entry, descent, and landing (EDL) technologies that will enable large masses (up to 1 ton) to be landed on the Martian surface. NASA has gained the knowledge to build scientific instruments to sample the air, collect and analyze minerals, and to characterize radiation environments. In a similar example, the NASA also has a number of missions to the Moon and to asteroids that provide essential information for human exploration of these bodies. While the Human Exploration and Operations Mission Directorate is developing the transportation system to go beyond low Earth orbit, planetary science continues to make steady progress in developing the right knowledge and expertise in support of future exploration.

2) Each Mars mission relies on past missions for proven technologies and contributes its own innovations to future missions. This chain allows NASA to push the boundaries of what is currently possible, while still relying on proven technologies. Please provide some examples of key technologies whose evolution made MSL possible.

Response: Technologies and innovations evolved from prior missions, or developed through Planetary and Mars technology programs, are critical to enabling engineering solutions and discoveries. A broad range of these technologies have made MSL possible, such as:

- The parachute for MSL (and every prior landed Mars mission) is derived from the Viking landers design from the 1970s. MSL significantly expanded the capability by employing computational fluid dynamics running on NASA supercomputers and tested in NASA wind tunnels at Ames Research Center, to create the largest parachute ever flown to Mars.
- The main landing engines on the MSL Skycrane descent stage were developed and qualified as new technologies, and have since been re-qualified for use by orbiters as Mars Orbiter Insertion engines.
- The descent stage's radar and bridle systems that land the rover softly on the surface were invented for Pathfinder and MER missions and adapted for MSL.

- The 6-wheeled "rocker-bogie" mobility system designed to traverse rocky Martian terrain was first proven on the 1996 Mars Pathfinder mission, and enlarged and adapted for Spirit & Opportunity and MSL. It is now part of the MSL landing system too, since MSL lands on its wheels rather than a platform.
- Curiosity's semi-autonomous navigation software has been evolving with use by Spirit & Opportunity on Mars, incorporating over 8 years of driving and navigation experience.
- Curiosity's power source, the multi-mission radioisotope thermoelectric generator (MMRTG), developed with the Department of Energy, evolved from the Pioneer, Voyager, Viking, Ulysses, Galileo, Cassini, and New Horizons missions, and is now designed as an "off-the-shelf" power source for future planetary missions.

MSL will prove out technologies and enhancements that will be incorporated into future Mars rover missions, the most important of which is the Skycrane landing system. The Mars Program has always intended that the Skycrane be used as a build-to-print system to provide 1 metric ton landing capability using the aeroshell, and cruise and descent stages. It can be employed for future science missions, human precursor investigations, or possibly even astronaut resupply.

3) Did your Division or the NASA Science Mission Directorate propose the cuts to the Mars Program that were included in the President's FY12 Budget request of last February?

- *If not, were they directed by OMB?*
- *Did the reductions to the Mars Program over the past 12 months come at the direction of OMB rather than from inside NASA?*
- *In cases where NASA and OMB disagree over the proposed budget, who has the last word – NASA or OMB?*

Response: NASA fully supports a fiscally responsible and scientifically viable Mars Exploration Program in the larger context of the Nation's budget. NASA works with OMB to develop the President's Budget Request consistent with the Administration's priorities. NASA executes its current fiscal year program as provided via appropriation from Congress.

From Representative Donna Edwards

1) *Has NASA officially communicated its commitment to the European Space Agency (ESA) on the joint Mars initiative? If not, what is NASA's timeline for providing a formal commitment to ESA on the joint initiative?*

   Response: No. The uncertainty in the future budget outlook has prevented us from making a commitment to the joint Mars 2016/2018 mission architecture we have been studying with ESA. NASA and ESA have kept each other informed of the status of our respective budget situations.

2) *What are the prospects for carrying out the first leg of the Mars Sample Return campaign within the next decade?*

   Response: Plans for future robotic exploration of Mars will be proposed in early February, along with the FY 2013 budget request.

3) *What are the Europeans prepared to spend on the joint Mars initiative and to what extent could that level of spending enable the U.S. to carry out the 2016 trace orbiter and the first stage of the Mars Sample Return Mission?*

   - *What level of spending would be required from the U.S. to make this joint effort possible?*
   - *When does ESA need a final commitment from NASA as to NASA's participation in the 2016 and 2018 missions?*

Response: The Europeans have committed 1B Euros (~$1.3B) to the combined joint 2016 and 2018 Mars missions. This level of spending in Europe represents a significant contribution of labor and finances for the US. NASA has not established a baseline for either mission, but the agency's preliminary estimate is that the potential U.S. contribution to the combined 2016 and 2018 mission set would be about $2.5B. ESA requested a US commitment earlier this year, as they are already spending money on these two missions. NASA recently informed ESA that we were not able to commit to either of these missions any earlier than the release of the FY 2013 President's Budget request to Congress in February 2012.

4) *Your prepared statement indicates that NASA is "studying the implementation of the Mars 2016 and Mars 2018 missions with ESA within available budgetary resources."*

   - *Please explain what is meant by "studying the implementation"?*
   - *Although the Mars 2016 and Mars 2018 missions are really components of the same mission, one for the orbiter and the later mission for roving and caching, is one of the options being considered that of limiting U.S. participation to only one of those missions?*
   - *What budgetary scenarios are being considered?*
   - *Were these scenarios established by OMB?*

Response: By "studying the implementation" we mean that we have been conducting engineering and cost assessments of various options for accomplishing the potential Mars 2016 and Mars 2018 missions with ESA. We have jointly with ESA selected and begun Preliminary Design Reviews (PDR) on trace gas instruments and communications equipment that would fly on the 2016 mission if it were approved. ESA has conducted PDRs on their orbiter as well. Studies for the potential 2018 mission included a scenario for U.S. participation only in the Mars 2018 mission. NASA considered budgetary scenarios consistent with the notional outyear profile submitted with the FY 2012 budget request. The budget levels and scenarios were discussed with OMB in the FY 2012 and FY 2013 budget processes.

5) During the hearing you said that NASA's approach is "to continue to work with ESA, continue to find ways to lower our costs and meet both of the objectives from European Space Agency and for NASA." What steps have been taken to lower costs in the 2016 and 2018 mission plans?

Response: NASA has taken significant steps to reduce and control costs on these two potential missions. For the 2016 mission, ESA would provide the spacecraft bus and operations team—a significant savings. To reduce and control NASA costs, we restricted instrument requirements and U.S. science team size to the minimum, descoped the U.S.-provided Ka-Band high data-rate radio, and we are building the "ELECTRA" surface-to-orbit radio as an identical copy of the 2013 MAVEN mission's radio. To reduce and control 2018 mission costs NASA and ESA descoped the original concept of 2 rovers (ESA/NASA) landed on a platform to a single, jointly developed rover that would not require a platform. This single joint rover approach also maximizes the use of MSL spare hardware and existing designs by using the same aeroshell, cruise stage, and sky-crane in a build-to-print fashion, to deliver the rover to the surface. The rover would be designed to maximize reuse of MSL components for the NASA contributions. Concurrently, this significantly reduces new technology requirements and removes duplicate systems and science instruments while still maintaining the science objectives of both agencies. Early production of MSL-derived hardware for 2018 is another cost control technique, utilizing the existing workforce, expertise, and suppliers as they roll off the MSL project.

6) What does the United States stand to lose if it does not collaborate with Europe on future Mars launch opportunities in 2016 and 2018?

Response: The immediate and tangible US losses include nearly three years of negotiation and engineering/scientific effort, more than $40M invested to-date in the 2016 orbiter mission.

7) What are the criteria for deciding on how offsets to fund the necessary increases for the James Webb Space Telescope will be made within the Science Mission Directorate and to what extent with the Mars program be affected?

Response: The criteria include minimizing impact to missions currently in development. NASA plans to implement offsets for the James Webb Space Telescope as provided via

appropriation from Congress in 2012. NASA will propose offsets in future years in future budget requests.

8) If NASA-ESA collaboration on Mars is not allowed to go forward, what will be the impact o the NASA Jet Propulsion Laboratory (JPL) in California, the nation's premier resource for planetary exploration?

- *How hard will it be for JPL and the nation to preserve the skills and capabilities needed to land on Mars at some point in the future if the planned NASA-ESA collaboration is not approved?*
- *What is the mood at JPL—are they nervous about the future after Mars Science Lab is launched?*
- *What are the implications for other contractor and NASA workforce should the NASA-European collaboration for Mars robotic exploration fall apart?*

Response: If the NASA/ESA collaboration on Mars 2016 and 2018 does not go forward the impact is directly tied to the alternate plans that are pursued instead. If the NASA/ESA collaboration does not go forward and there are no alternate activities that take advantage of the JPL workforce, the impact on JPL will amount to several hundred layoffs as the MSL team wind down cruise and entry, descent, and landing (EDL) operations. The impact would include the key engineering areas of EDL and surface robotic operations. The ability to capitalize on the investments in MSL would deteriorate rapidly, extending beyond JPL to the industrial base and supply chain that supports this unique EDL and surface capability. JPL is maintaining its focus on upcoming MSL landing, but there are clearly apprehensions in the work force of what lies ahead in the FY 2013 budget and beyond for Mars exploration.

Responses by Dr. Steve Squyres, Chair,
Committee on the Planetary Science
Decadal Survey, National Academies of Science

Questions submitted by Subcommittee Chairman Steven Palazzo

Q1. Your testimony cites the importance of a balanced program, and included in such a program is the Research & Analysis (R&A) component. It is this program where discoveries are generated, where analysis is conducted, and where opportunities to train our future scientists begin. Is the R&A account being unjustly raided to pay for the more visible programs, such as the flagships? How do you recommend preserving the vital balance among different sized programs given current budgetary constraints?

A1. It has not been my impression that the R&A program has been unjustly raided to pay for other programs. On the contrary, NASA management has done a good job to date of protecting the R&A program, as recommended in the decadal survey report. The decadal report recommends specific levels of R&A funding for the decade 2013–2022, and states that high priority should be placed on preserving this funding. Some flexibility in R&A funding in the face of declining budgets, however, is consistent with the decadal recommendations.

Q2. In your view, can NASA meet its mission objectives for Mars 2018 and the future Mars Sample Return missions without flying Mars 2016?

A2. I know of no technical reasons related to Mars 2018 and beyond that require the Mars 2016 mission to be flown. There could, however, be a programmatic reason. Strong participation by the European Space Agency (ESA) in the Mars missions in 2018 and beyond is necessary in order for them to be affordable to NASA. If NASA were to pull out of the 2016 mission, this action could threaten the partnership with ESA for 2018 and beyond.

Questions submitted by Ranking Member Jerry Costello

Q1. What puts the Mars program in the must-have category as opposed to the nice-to-have category? How can I convince my colleagues in Congress and my constituents that Mars is of national importance in these fiscally constrained times?

A1. Mars is unique among the planets in being enough like Earth that we can imagine life once having taken hold there. This means that Mars is a place that we can go to seek answers to truly basic questions like whether we are alone in the Universe, and how life began. Such questions are among the most important faced by science, and are of interest to every thinking person. It is these characteristics that make Mars special.

Q2. How important is it for the United States to maintain its leadership in Mars exploration following the launch of the Mars Science Laboratory? What is needed now in order to sustain our Nation's leadership in Mars robotic exploration?

A2. I believe it is crucial for the United States to maintain this leadership, both because of the importance of Mars science that I cited above, and the difficulty of re-establishing this leadership if it is lost. In order to sustain our leadership position, a new high-priority mission of Mars exploration is needed—like the Mars Sample Return campaign recommended by the planetary decadal survey.

Q3. Congress, through the House and Senate appropriations bills for FY 12, and through successive Authorization Acts, has supported a robust planetary science program, including robotic Mars exploration. What criteria should Congress use to evaluate any proposals that would disrupt the systematic robotic exploration of Mars that has been built-up over the past decade?

A3. I believe that the appropriate criterion to use is consistency with the recommendations of the National Research Council's planetary decadal survey. This survey involved inputs from more than a thousand professional planetary scientists, and represents the consensus recommendations of that community to the United States government regarding NASA's planetary program.

Q4. If the U.S. reneges on the joint Mars initiative with ESA, what would be the impact of a hiatus in our ability to sustain knowledge of the Red Planet?

a. Would we be ceding hard-earned leadership to other countries?

A4 (a). It's likely. We certainly would be giving up hard-earned leadership, and there are many other national and international space agencies that have both the capability and the intention to take on a leading role in Mars exploration.

b. Would other countries view us as an unreliable partner in future space endeavors?

A4 (b). In my opinion, that would be a very serious risk.

Q5. NASA has many technical capabilities. Why is the ability to land and rove on Mars, which you refer to as being a national "crown jewel", so hard to master and what would be the implication if the United States stood down its robotic exploration of Mars for a period of time?

A5. Landing and roving on Mars is so difficult because it is impossible to predict the exact environmental conditions in the martian atmosphere and at the martian surface. Any such spacecraft, therefore, must be capable of surviving a wide range of possible conditions. Landing and roving on Mars is, in my opinion, the most difficult thing we do in planetary exploration. If we stand down our robotic exploration of Mars for a long time it will be very difficult to re-start it, due to the loss of critical workforce.

Q6. How important are the strategic capabilities, scientific knowledge, and technical experience that the U.S. has gained through Mars and planetary science missions to NASA's future plans for solar system exploration and human exploration beyond low-Earth orbit?

A6. They are crucial. The most important long-term target for human space exploration is Mars. Today's robotic Mars program is laying the essential groundwork for the future program of human Mars exploration.

Q7. With the prospects of flat or reduced budgets for planetary sciences, NASA will be challenged to initiate expensive flagship missions while also maintaining a balanced program that includes small and medium-sized missions. What are the options for pursuing top-priority flagship missions and how should Congress weigh those options?

A7. Three approaches are crucial to making flagship missions affordable. First, flagship mission development should be characterized by adequate up-front investment in technology development, and very conservative cost estimation practices. These work together to reduce the risk of future overruns. Second, the scope of flagship missions must be limited and in some cases reduced. The planetary decadal survey report recommended substantial descoping of the two highest priority planetary flagship missions, including the 2018 Mars sample caching rover mission. Third, NASA should vigorously pursue strategic partnerships with capable international partners like ESA to reduce the total cost to the U.S. of high priority flagships.

Questions submitted by Subcomittee Ranking Member Donna Edwards

Q1. In your prepared statement, you note that "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 return collection and caching mission." Could you please explain the budget guidelines to which you are referring and why you believe the Agency could carry out the Mars missions under those guidelines?

A1. I am referring to the sharply-decreasing five-year projection for the NASA planetary science budget provided in the FY 2012 budget request. Specifically, those numbers were $1,488.9M in FY'12, $1,365.7M in FY'13, $1,326.4M in FY'14, $1,271.0M in FY'15, and $1,188.9M in FY'16. I believe the Agency could carry out the Mars program even under those very harsh guidelines because of the substantial progress they have made in reducing the scope of the program—most notably reconfiguring the 2018 mission to include just one rover.

Q2. The planetary science decadal survey committee, which you chaired, recommended Mars Sample Return as its top priority in the large mission category over the next decade.

a. What guidance did the committee provide on how this priority should be treated within a severely constrained fiscal environment?

A2 (a). The decadal guidance on this point had three main components. First, it recommended that Mars Sample Return only be carried if the cost to NASA of the 2018 mission could be reduced to no more than $2.5 billion. (Current projections are sub-

stantially less than that.) Second, it recommended that it only be carried out if a partnership with ESA could be arranged for the entire Mars Sample Return campaign. Third, it recommended that if severe cuts to NASA's planetary program become necessary, they should be implemented by descoping or delaying (but not eliminating) flagship missions.

b. How does uncertainty in the Mars program planning for 2016 and 2018 launch opportunities affect capabilities needed to implement Mars Sample Return?

A2 (b). It affects it in several ways. One is that the 2018 mission is intended to kick off the Mars Sample Return campaign with a sample collection and caching rover. If that mission becomes uncertain, the whole campaign becomes uncertain. Another is that uncertainty in 2016 and 2018 could weaken or ruin the partnership with ESA, which is necessary to make Mars Sample Return affordable to NASA. Finally, as I discuss below, uncertainty in 2016 and 2018 could lead to loss of critical workforce capabilities within NASA, particularly at the Jet Propulsion Laboratory.

Q3. Some argue that funding to enable NASA to implement the planetary science decadal survey priorities should be taken from the nation's human spaceflight program. In your view, is that a good idea or not?

A3. In my view, that is a very bad idea. Human spaceflight has always been central to the goals of NASA, and my personal opinion is that it should remain central to those goals.

Q4. With respect to offsets for the increases required to fund the James Webb Space Telescope, has the science community within NASA or external to NASA been asked for input on how those offsets are to be made, especially with respect to planetary science?

A4. I am not aware of any requests to the science community for input on how such offsets should be made.

b. *Has NASA or the Office of Management and Budget shared any proposals on how those offsets might be made, and if so, what is your reaction?*

A4 (b). I am not aware of any publicly available proposals for how such offsets might be made. I presume that OMB's intentions on this point will be made clear in the FY'13 budget submission.

Q5. If the NASA-European Space Agency (ESA) collaboration on Mars is not allowed to go forward, what will be the impact on the NASA Jet Propulsion Laboratory (JPL) in California, the nation's premier resource for planetary exploration?

A5. I fear it will be substantial. Specifically, I am deeply concerned about the potential loss of some of the most talented members of JPL's workforce.

b. *How hard will it be for JPL and the nation to preserve the skills and capabilities needed to land on Mars at some point in the future if the planned NASA-ESA collaboration is not approved?*

A5 (b). It will be extremely difficult. The people at JPL who know how to land on Mars are some of NASA's best. And they don't just know how to land on Mars—they are aerospace engineers with broad talents and deep knowledge. They are people who are drawn to a challenge and who have skills that are much in demand. If there is no new planetary exploration challenge for them to meet within NASA, I fear that they will go elsewhere.

c. *What is the mood at JPL—is the workforce nervous about the future after Mars Science Lab is launched?*

A5 (c). In my recent conversations with scientists and engineers at JPL, the mood is very nervous. The Laboratory is justifiably proud of recent successes at Mars, and people are excited about the prospects for new discoveries with MSL. But JPL's bread and butter is development of new deep space missions, and unless there will be a flagship planetary mission after MSL, JPL's workforce faces major uncertainties.

Q6. What has been the impact of America's systematic approach to Mars exploration on inspiring the next generation to pursue science and engineering careers?

A6. I believe it has been substantial. I have received dozens, perhaps hundreds, of emails and letters from students and parents telling me how the career goals of young people have been shaped by the excitement generated by NASA's Mars program. I honestly believe that this inspiration may ultimately be one of the most im-

portant legacies of the Mars program, in the same way that inspiring today's space scientists and engineers—myself included—was a major legacy of Apollo.

Q7. Is there any way to measure how a reduction in the pace of Mars exploration or a stand down in Mars missions would affect student interest in science and engineering?

A7. That strikes me as a difficult quantity to measure, but I am not an expert in educational metrics. Perhaps that would be a good question to pose to NASA's Education Program.

Appendix II: Additional Material for the Record

SUBMITTED STATEMENT FOR THE RECORD BY THE PLANETARY SOCIETY

November 15, 2011

Statement by
The Planetary Society

before the

Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives

Hearing: Exploring Mars and Beyond: What's Next for U.S. Planetary Science?

"Of all discoveries and opinions, none may have exerted a greater effect on the human spirit than the doctrine of Copernicus. The world has scarcely become known as round and complete in itself when it was asked to waive the tremendous privilege of being the center of the universe."
—Johann Wolfgang von Goethe

In the 16th Century, Nicolaus Copernicus proposed a revolutionary theory—that the Earth revolves around the Sun, just like any other planet. This event stands as a seminal moment in human history. Copernicus' theory, coupled with subsequent discoveries in astronomy and planetary science, is the spark that ignited the scientific revolution. This intellectual awakening laid the foundation for modern science including physics, chemistry, biology and medicine, as well as engineering and technology. These discoveries in turn led to revolutions in religion, philosophy, and politics, which brought about the Age of Enlightenment, eventually led to the American Revolution, and fundamentally influenced American ideals and our way of life. It is impossible to overemphasize the impact that the study of the Cosmos has had on humankind, the human spirit, and our collective search for our place in the Universe. Yet, there is still much to learn.

We stand at the dawn of a similar period in which our knowledge and understanding of the Universe is poised to take another giant leap forward. Recent planetary science missions reveal a solar system filled with worlds begging for further exploration. Recent discoveries include water ice on the Moon's poles, evidence for an early warm and wet climate with potential conditions for life on Mars, liquid oceans under the surface of Jupiter's moon Europa, and liquid hydrocarbon lakes on Saturn's moon Titan. At the same time, astronomers have discovered

hundreds of new planets orbiting other stars, allowing scientists to study how other planetary systems formed and how they behave so we can learn more about our own.

These remarkable discoveries point to a rich and diverse solar system and provide tantalizing clues to whether life exists elsewhere. For the first time in human history, we have the tools available to directly test the hypothesis of whether there is, or has been, life on other worlds such as Mars or Europa. Such a discovery would have the potential to spark a new scientific revolution.

The Planetary Society believes that a strong and vibrant planetary and space science exploration program is critically important to the nation, and to all humankind. We believe no other endeavors provide greater science value for the dollar and inspiration for the public than astronomy and planetary science.

The Society strongly supports the findings and recommendations of the National Research Council's decadal survey, "Vision and Voyages for Planetary Science in the Decade 2013-2022." We believe the program recommended in the survey, including the exciting and valuable flagship missions to Mars and Europa, provides a compelling case for a robust planetary science program. The survey represents a well-thought-out set of priorities and achievable programs that strikes the appropriate programmatic balance and balance of destinations across the solar system. Equally important, the survey provides clear guidance and decision rules to adjust priorities to respond to the changing budget environment. To be clear, the decadal survey's rules for descoping missions emphasize the need to maintain a balance, including maintaining a flagship mission, in the face of budget reductions.

We also support NASA's priority for the James Webb Space Telescope. With its major advances beyond the Hubble Space Telescope, Webb will have the power to detect the presence of liquid water on planets just a few times larger than the Earth that are orbiting around other stars. It will also be a unique tool for studying many of the worlds within our own planetary system, especially the small cold bodies that are thought to have carried water and the seeds of life to our nascent Earth in the earliest epochs of the Solar System's formation.

Planetary science is rich with exciting potential missions, destinations and science, but its reach is limited by financial resources. With the intense fiscal pressure facing all agencies, NASA must focus on making the most efficient use of the money it gets—and this means setting priorities and making decisions based on merit and where the money can be used most effectively.

Today, approximately 27 percent of NASA's budget goes to Science, with 8 percent of NASA's total going to Planetary Science. The human spaceflight program (SOMD+ESMD) consumes about 45 percent of NASA's budget, and the remaining 28 percent goes to aeronautics, technology and infrastructure. The Planetary Society is a strong supporter of both human and robotic space exploration and a strong advocate for investments in technology. However, given the budget outlook, we believe a close examination of the balance of funding across these areas is warranted and that some minor adjustments are needed.

Specifically, the Planetary Society recommends reallocating approximately 3 percent from within NASA's total budget to rebaseline the share for Science to at least 30 percent, or about $5.4 billion for FY12 based on the Senate mark of $17.9 billion (which already includes funding for the James Webb Space Telescope). This modest rebalancing will allow NASA to fully implement the decadal survey for Planetary Science, including the currently proposed NASA/ESA joint mission to Mars, and allow NASA to complete the James Webb Space Telescope, and to continue a robust program of missions in Earth Science, Astronomy and Heliophysics.

We arrive at this conclusion primarily because NASA's Science program currently has an abundance of compelling world-class science missions with clearly defined mission goals and carefully crafted program plans that are poised to move out. We believe that a healthy and vibrant Science program is an excellent investment that will energize, engage, and inspire the next generation of scientists, engineers, educators and the public, as has been the case with the Mars rovers and many other missions. The diversity and frequency of science mission opportunities laid out by the decadal survey will significantly contribute to thousands of high-

tech jobs in the aerospace industry, at research laboratories, and in universities. These programs will stimulate the best and brightest with interesting and meaningful scientific and technical challenges that will make our nation stronger and more competitive.

We have also taken into consideration and carefully weighed the impact on other NASA programs we support, such as human space exploration, and concluded that, at this time, the human space exploration program does not have sufficiently clear mission goals and implementation plans to justify the level of funding proposed in the near-term. This should not be construed as a lack of support for the mission, but a recognition of the reality that the program is not in a position to use the funding as effectively as the Science program. The Planetary Society is, and will continue to be, a staunch supporter of a bold and exciting human spaceflight program. To this end, the Society supports the independent strategic assessment of NASA's mission and goals proposed by the House Appropriations Committee in the FY12 Commerce, Justice, Science Appropriations bill and we offer our help in trying to forge an exciting and achievable plan for human spaceflight.[1]

While we recognize these are difficult choices, we believe an increase in the share of the NASA budget for Science to 30 percent is the best place for the agency to make the most effective use of the taxpayers' money at this time and in today's budget environment.

We are at the brink of the next revolution in scientific understanding. A great government will lead this pursuit and makes these investments because it will make a difference to our society and to our children.

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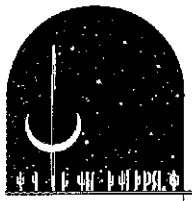
[1] *Comprehensive independent assessment.*--The Committee has been frustrated by the uncertainty of leadership within the Administration on space policy and the resulting lack of focus within NASA itself. It is time for NASA to recommit itself to a bold vision for the future that will restore the sense of purpose and urgency that existed at the agency during the eras of its finest achievements. Accordingly, the Committee recommendation includes $1,000,000, which shall be for transfer to the CIG, to commission a comprehensive independent assessment of NASA's strategic direction and agency management. H.R. 2956; H-Rpt 112-169

The Planetary Society

The Planetary Society, founded in 1980 by Carl Sagan, Bruce Murray, and Louis Friedman, inspires and involves the world's public in space exploration through advocacy, projects, and education. Today, The Planetary Society is led by Bill Nye, Executive Director. The Society is the largest and most influential public space organization group on Earth with 50,000 current members and a worldwide community of over 100,000. Dedicated to exploring the solar system and seeking life beyond Earth, The Planetary Society is non-governmental and nonprofit and is funded by the support of its members.

SUBMITTED STATEMENT FOR THE RECORD BY DR. MARK SYKES, CEO AND DIRECTOR OF THE PLANETARY SCIENCE INSTITUTE



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Founded 1972

STATEMENT TO
THE SUBCOMMITTEE FOR SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Re: Exploring Mars and Beyond: What's Next for U.S. Planetary Science?

Mark V. Sykes, Ph.D., J.D.
November 15, 2011

Space exploration is often thought of in terms of high profile, large and expensive missions. Yet in solar system exploration, these "Flagship" missions are but one component of a larger enterprise that rests on a foundation of basic research, integrative studies of returned data from missions small and large, technology development programs and ideally more frequent, smaller Discovery/Scout class missions. If the United States is going to have a future in solar system exploration, the health of these foundational programs must be given priority. Focusing on Flagship missions without first ensuring the health of these foundational programs is like taking a final exam after skipping classes, not doing your homework, and expecting to get an 'A' and have a high-paying job waiting for you.

Unlike NASA astrophysics missions, which are generally space-based telescope facilities to which a broad range of targets can be observed and science questions addressed, NASA planetary missions are necessarily very focused endeavors in which the science undertaken is usually specific to a single target (e.g., Venus) or system of objects (e.g., Saturn). From Mercury to the outermost regions of the solar system, the U.S. has not limited the range of targets to which it may send planetary missions. This requires basic research and analysis of past spacecraft data to know what are the questions that can only be addressed by spacecraft, what are the appropriate instruments needed to address them, and what informational context is required. Without this work, the American taxpayer cannot get the maximum science return for their tax dollar spent on missions of any size.

The health of planetary research and data analysis programs today is poor.

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In FY2010, approximately 10% of program funding was reallocated from those programs to other purposes by rephasing funds to FY2011. However, no additional funds were added to these programs in 2011 to cover the rephased obligations. The result was an estimated drop in new research awards of about one-third to planetary scientists around the country. In the current fiscal year, the present operating plan for the Planetary Science Division has cut research programs from their 2011 levels, with the potential impact of no awards for some programs in 2012 unless the operating plan is modified. The potential impact will be significant, negative, and long-lasting. Scientists and their skills and knowledge will be lost and not recovered. This is a wound to our nation's solar system exploration capabilities that is self-inflicted by NASA - not Congress and not OMB.

The importance of these programs have been highlighted in numerous NRC reports (e.g., An Enabling Foundation for NASA's Earth and Space Science Missions, 2010; Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, 2007; Supporting Research and Data Analysis Programs: Engines for Innovation and Synthesis, 1998). Most recently, the "planetary decadal survey" (Vision and Voyages for Planetary Science in the Decade 2013-2022, 2011) place it among the highest priorities, even in an era of declining budgets, noting

> "It is also possible that the budget picture could be less favorable than the committee has assumed. If cuts to the program are necessary, the first approach should be descoping or delaying Flagship missions. Changes to the New Frontiers or Discovery programs should be considered only if adjustments to Flagship missions cannot solve the problem. *And high priority should be placed on preserving funding for research and analysis programs and for technology development.*" (italics added)

The current actions by NASA are also contrary to decadal survey recommendations:

> "Increase funding for fundamental research and analysis grant programs, beginning with a 5 percent increase above the total finally approved fiscal year (FY) 2011 expenditures and then growing at an additional 1.5 percent per year above inflation for the remainder of the decade (Chapter 10). This increase will enable the full scientific benefits of ongoing and future flight projects to be reaped."

They are also inconsistent with the commitment by NASA in its response to the decadal survey to maintain the funding levels of these programs at the FY11 levels (http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412).

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While concern about budgets for large new flagship missions is appropriate, our national interest is not served by cutting research and data analysis programs, technology development programs, and ongoing missions in an effort to create an otherwise unfunded wedge for their development. In the event that difficult fiscal times are realized in the NASA budget, common sense dictates that prioritizations be made. The planetary decadal survey has laid out those priorities.

Planetary research and data analysis programs should be fully funded with committed budgets at this time, even under CR, and even under the threat of reduction of funding to the agency as a consequence of overall deficit reduction measures. Our future in solar system exploration depends upon it.

Sincerely,

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