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

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

November, 15 2011
10 a.m. – 12 p.m.
2318 Rayburn House Office Building

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 de-scoping 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."[1]

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*

[1] Vision and Voyages for Planetary Science in the Decade 2013-2022, National Academies of Science, Washington, DC, March 2011. ES-1

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.[2]

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.[3]

[2] Visions and Voyages, p. ES-4
[3] Ibid., p. 9-23.

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.*[4]

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*

[4] Vision and Voyages, p. 9-24.

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[5] 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.

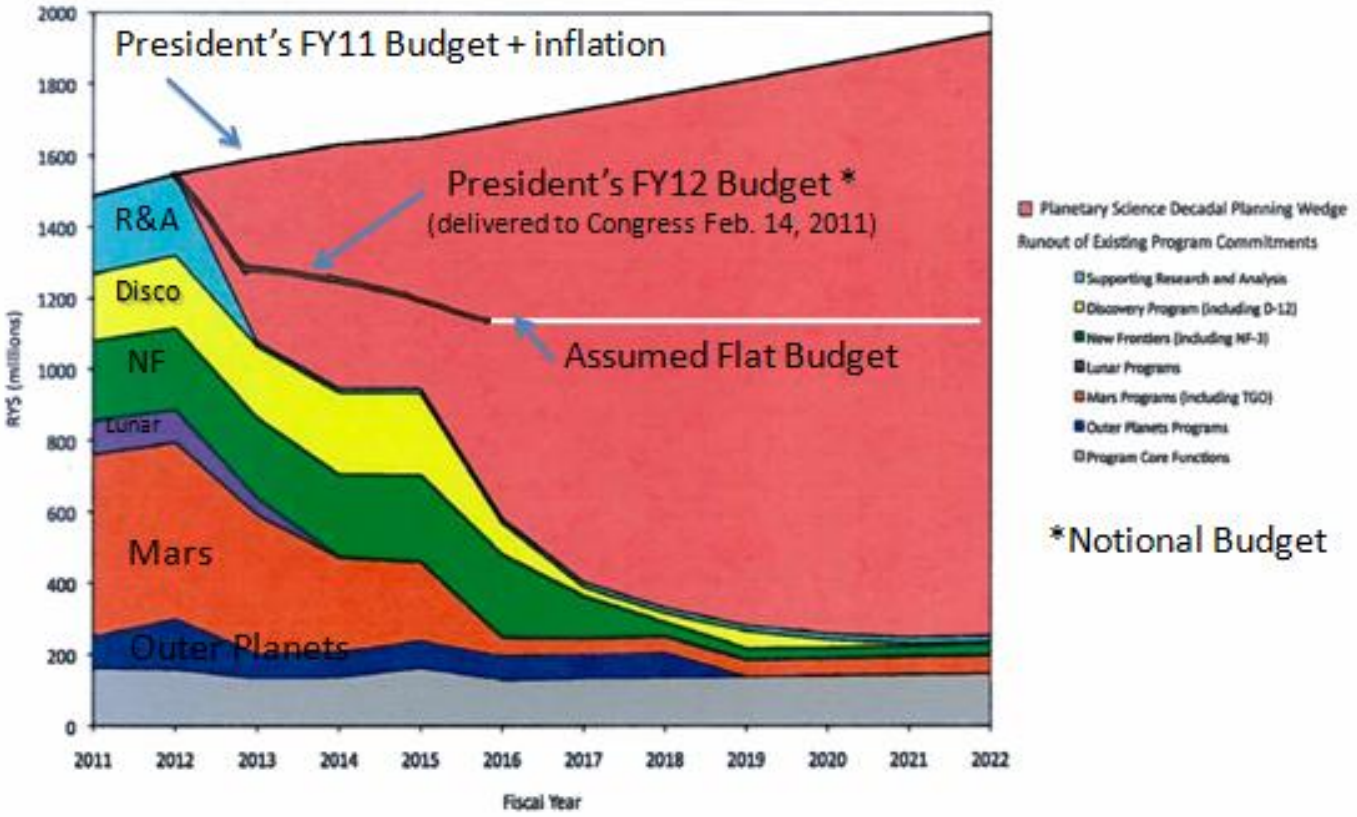
The Senate approved its FY12 budget for NASA on November 1, 2011 providing $1.5 billion for Planetary Science. *See Appendix A for a complete breakdown by mission area*. In its report, the committee states:

> 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.

[5] H.R. 2596, the Commerce, Justice, Science and Related Agencies Appropriations Act, 2012

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)**