# U.S. HOUSE OF REPRESENTATIVES
# COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
# FULL COMMITTEE

## *Exploring Our Solar System: The ASTEROIDS Act as a Key Step*

Wednesday, September 10, 2014
10 a.m. – 11:30 p.m.
2318 Rayburn House Office Building

## Purpose

On Wednesday, September 10, 2014 the Subcommittee on Space will hold a hearing to review numerous issues facing planetary exploration of our solar system, including NASA's proposed budget for planetary science, low inventories of Pu-238 for deep space missions, and potential commercial interests. Witnesses have been asked to testify on H.R. 5063, the American Space Technology for Exploring Resource Opportunities In Deep Space (ASTEROIDS) Act.

## Witnesses

- **Dr. Jim Green**, NASA Planetary Science Division Director
- **Dr. Jim Bell**, Professor of Earth and Space Science Exploration, Arizona State University, and President, Board of Directors, The Planetary Society
- **Dr. Mark Sykes**, CEO and Director, Planetary Science Institute
- **Professor Joanne Gabrynowicz**, Professor Emerita, Director Emerita, Journal of Space Law Editor-in-Chief Emerita, University of Mississippi
- **Dr. Philip Christensen**, Co-Chair, NRC Committee on Astrobiology and Planetary Science (CAPS), Chair, Mars Panel, NRC Planetary Decadal Survey, Regents Professor, Arizona State University

## Background

### *Budget for NASA's Science Mission Directorate*

| | Actual | Enacted | Request | FY14 Vs | Notional | | | |
|---|---|---|---|---|---|---|---|---|
| **Budget Authority ($ in millions)** | **2013** | **2014** | **FY15** | **FY15** | **2016** | **2017** | **2018** | **2019** |
| **Science** | **4,781.6** | **5,151.2** | **4,972.0** | **(179.2)** | **5,021.7** | **5,071.9** | **5,122.6** | **5,173.9** |
| Earth Science | 1,659.2 | 1,826.0 | 1,770.3 | (55.7) | 1,815.4 | 1,837.6 | 1,861.9 | 1,886.3 |
| Planetary Science | 1,274.6 | 1,345.0 | 1,280.3 | (64.7) | 1,304.9 | 1,337.1 | 1,355.7 | 1,374.1 |
| Astrophysics | 617.0 | 668.0 | 607.3 | (60.7) | 633.7 | 651.2 | 696.8 | 933.0 |
| James Webb Space Telescope | 627.6 | 658.2 | 645.4 | (12.8) | 620.0 | 569.4 | 534.9 | 305.0 |
| Heliophysics | 603.2 | 654.0 | 668.9 | 14.9 | 647.6 | 676.6 | 673.3 | 675.5 |

The Science Mission Directorate (SMD) conducts scientific exploration enabled by the observatories and probes that view Earth from space, observe and visit other bodies in the solar system, and gaze out into the galaxy and beyond.[1] The directorate has four divisions; Earth Science, Planetary Science, Astrophysics and Heliophysics. NASA is requesting $4.972 billion for SMD in FY15, which is a reduction of approximately $179.2 million (four percent) below the FY14 enacted level.

The SMD Planetary Science division is responsible for monitoring and analyzing data collected from NASA missions exploring the solar system in the search for the content, origin. and evolution of the solar system as well as the potential for life. Additionally, Planetary Science is responsible for Near Earth Object Observations program. The budget for the Planetary Science division has decreased from $1.485 billion in the FY11 request, to $1.280 billion in the FY15 request.

NASA's FY15 budget request included a line item of $15 million to begin designing a mission to Europa, one of Jupiter's moons that is covered with ice water. Since water is one of the fundamental ingredients for life, Europa holds promise that life may exist elsewhere than Earth. Congress has demonstrated support for a Europa mission, one of the priorities from the National Academies of Science decadal survey for planetary science.[2] The Administration's funding request is only for FY15, with no money budgeted in the out-years for a Europa mission. The Administration typically identifies a funding wedge of budget authority in the outyears, so the Administration's support for a Europa mission beyond FY15 is uncertain.

***FY2015 Budget***

Generally, there has been bipartisan support for NASA funding in both chambers of Congress. In June, the House passed the NASA Authorization Act of 2014 by a vote of 401 to 2. In May, the House passed the Commerce-Justice-Science appropriations bill (H.R. 4660) by a bipartisan vote of 321 to 87. The bill would fund NASA at $435 million more than the President's FY15 budget request.[3]

H.R. 4660 provides $5.193 billion for SMD, an increase of $221 million from the President's FY15 budget request of $4.972 billion. Within that provision the Planetary Science Division would receive $170 million more than the budget request.

The Senate Appropriations Committee approved an appropriations bill in June for $17.9 billion, $440 million more than the President's budget request. Within that bill, SMD would receive $5.2 billion, an increase of $23 million, of which $1.3 billion would be for Planetary Science.

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[1] National Aeronautics and Space Administration FY15 Budget Estimates – Science Mission Directorate (p. SCI-4)
[2] National Research Council. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. p. 268, Appendix C, p. 345. Washington, DC: The National Academies Press, 2011.
[3] H.R. 4660.

***Current Planetary Missions***

Planetary Science missions currently in operation and/or development include, in alphabetical order:

**Cassini (Cassini Solstice Mission) –** The Cassini mission has done numerous fly-bys of Saturn's moons, including Enceladus and Titan, which may harbor environments conducive to the existence of life. Cassini will end its third mission extension by examining the rings of Saturn and high-latitude mapping of Titan and Saturn.

**Dawn –** This mission is currently traveling between the oldest and largest bodies in the main asteroid belt between Mars and Jupiter. After launch in 2007, it orbited its first destination, the asteroid Vesta, in 2011, and is expected to reach the dwarf planet Ceres in February 2015. Dawn will compare and contrast each body to gain insights into the early years of the solar system.

**Europa –**NASA has begun to formulate a mission to study Jupiter's icy moon Europa. Pre-formulation is under way, including releasing a call for instruments.

**InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) –** InSight is a Mars lander mission, and is expected to launch in spring 2016. It will study the interior of Mars to understand how rocky planets (like Earth and Mars) were formed, and investigate possible tectonic activity.

**Juno –** Juno launched in 2011, and will orbit over Jupiter's poles to conduct remote sensing observations and take never-before-seen images of the Jovian planet. It will be the first solar-panel powered spacecraft to orbit Jupiter.

**JUICE (Jupiter Icy Moons Explorer) –** In a partnership with ESA, this mission will explore Jupiter and its moon Ganymede. It is expected to launch in 2022 and reach Jupiter in 2030.

**LRO (Lunar Reconnaissance Orbiter) –** LRO orbits the Moon, and was launched in 2009 as part of a precursor mission for preparations to send humans back to the lunar surface. One of its primary purposes was to map potential landing sites for future human Moon exploration, but it also has provided more information about the Moon's geological features and the potential presence of ice and water.

**MAVEN (Mars Atmosphere & Volatile EvolutioN) –** Launched in 2013, MAVEN will orbit Mars and investigate the loss of its atmosphere and the possibility for habitability.

**Opportunity Rover (Mars Exploration Rover/MER) –** Opportunity landed on Mars in 2004, and continues to provide excellent science by making atmospheric observations and providing evidence of Mars' habitable past.

**Mars Express –** The U.S. contributed components for the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) and the Analyzer of Space Plasmas and EneRgetic AtomS (ASPERAS). These instruments examine the ionosphere and atmosphere of Mars to determine the potential for life on the planet.

**Mars Odyssey 2001 –** Measurements made by orbiting spacecraft Mars Odyssey have enabled scientists to create a mineralogical map that provides future missions with target areas in which to search for the potential existence of water, microbial life, and possible landing sites for human missions to the surface of Mars.

**MOMA (Mars Organic Molecule Analyzer) –** This instrument is the U.S. contribution to the ESA **ExoMars** program (Exobiology on Mars). It is the astrobiology instrument on Europe's 2018 rover.

**MRO (Mars Reconnaissance Orbiter) –** Launched in 2005, MRO has a powerful camera with which it captures detailed pictures of Mars' geology. The pictures are being used to determine possible future landing sites. MRO has provided photographic evidence of the existence of liquid on Mars. It also serves as a communication relay between Mars and Earth for the Mars rovers.

**Mars Rover 2020 –** This year the Science Definition Team announced the instruments expected to be included on the next Mars rover, when it launches in 2020. The rover will collect core samples for future return to Earth, conduct fine-scale imaging, determine mineral and chemical compositions, and determine the existence of past or present organic material. It will also conduct tests to determine if the right ingredients exist on Mars for production of oxygen for human use.

**Curiosity Rover (Mars Science Laboratory Curiosity Rover) –** Curiosity is collecting soil and rock samples and analyzing them to determine if conditions have existed to support microbial life. It has already found evidence that water flowed on the Martian surface that could have supported microbial life.

**MESSENGER (MErcury Surface, Space ENvironment, Geochemistry, and Ranging) –** This mission to Mercury was launched in 2004 and conducted its first flyby of the planet in 2008. It is attempting to answer six science questions: investigate why Mercury is so dense; map its geologic history; study its magnetic field; determine the size and make-up of its core; identify important volatiles in its exosphere; and better understand the unusual materials at its poles. MESSENGER is scheduled to complete its mission in the first half of FY 2015.

**New Horizons –** This is the first mission to examine Pluto and its moons Charon, Nix, Hydra, Kerberos and Styx. New Horizons was launched in 2006, and is expected to reach Pluto in July 2015. The mission will image Pluto, and gather information about its atmosphere and surface features. A potential extended mission could include traveling to the Kuiper Belt to examine study at least one icy mini-world.

**OSIRIS-REx (Orginis-Spectral Interpretation-Resource Identification-Security-Regolith Explorer) –** The spacecraft is expected to launch in 2016 and will examine the asteroid Bennu and return a physical sample of the asteroid to Earth.

**Rosetta –** Rosetta is a European Space Agency (ESA) led mission to rendezvous and land on Comet Churymov-Gerasimenko (C-CG) in 2014. Launched in 2004, the Rosetta spacecraft was placed in hibernation until it came close to intercepting C-CG this spring. In August, Rosetta successfully rendezvoused with C-CG, and is expected to place a lander on the comet's surface in November.

***2014 Planetary Mission Senior Review***

On September 2, 2014, NASA released the results of the *2014 Planetary Mission Senior Review (PMSR)*. Conducted every two years, Senior Reviews recommend which Planetary Science missions should be extended, or not. Recommendations are based on presentations made by mission teams that show the scientific value of continuing the mission. Consideration is also given to how the costs of extending existing missions may impact the potential benefits of beginning new ones.

This year the Senior Review panel determined that the following missions should be extended:

- Cassini
- Lunar Reconnaissance Orbiter (LRO)
- Opportunity (Mars Exploration Rover/MER)
- Mars Reconnaissance Orbiter (MRO)
- Mars Express (MEX)
- Mars Odyseey (ODY)
- Curiosity (Mars Science Laboratory – MSL)

It should be noted that the older Opportunity Rover scored higher than the younger Curiosity Rover. Specifically, the panel felt that Curiosity's extended mission plan to take only eight samples in the next two years was not efficient and that "this is a poor science return for such a large investment in a flagship mission." The panel also found that "the proposal lacked specific scientific questions to be answered, testable hypotheses, and proposed measurements and assessment of uncertainties and limitations." Further, the panel expressed its concern that too much emphasis was placed on the distance the rover would travel, rather than the scientific analyses that could be conducted. Ultimately, the panel determined that the Curiosity team "felt they were too big to fail and that simply having someone show up would suffice."[4] The Mars Rover 2020 is expected to be designed to build upon Curiosity's science discoveries. Investigating the problems mentioned in the Senior Review could have important impacts on the Mars Rover 2020 program.

Below is a table that illustrates how each mission was rated.

[4] NASA's 2014 Planetary Senior Review, pp.5-6

| BUDGET | GUIDELINE | RECOMMENDED |
|---|---|---|
| **Mission** | **Rating** | **Rating** |
| Cassini | Excellent | |
| LRO | Very Good/Good | Excellent/Very Good |
| Opportunity | Excellent/Very Good | |
| MRO | Excellent/Very Good | |
| MEX | Good/Fair | Very Good |
| ODY | Very Good/Good | Very Good |
| Curiosity | Very Good/Good | Very Good/Good |
| Red = Recommended Grade and Budget. See individual mission reviews for details. | | |

Source: 2014 Planetary Mission Senior Review, p. 2

***Discovery-class Planetary Mission Announcement of Opportunity***

Discovery-class missions in the Planetary Science division are cost-capped, competitively awarded, smaller and less-expensive missions that explore the Solar Sytem. Missions are proposed and led by a senior scientist who serves as the Principal Investigator (PI) for the mission. In selecting Discovery missions, consideration is given to the priorities outlined in the latest planetary science decadal survey issued by the National Academies of Science.

On July 2, 2014, NASA released their Draft Discovery-class Planetary Mission Announcement of Opportunity (AO). The deadline for submitting a proposal is December 2014. The selected mission will be announced in spring 2015, and will be awarded in 2016. The mission must be ready for launch no later than December 31, 2021.

The latest AO for Discovery-class missions is the thirteenth announcement. The cost cap for missions is $450 million, not including the cost of the launch vehicle. This year's announcement also included proposal requirement changes from past announcements.

***Radioisotope Power Systems and the Inventory of Plutonium-238***

Plutonium-238 (Pu-238) is a by-product of nuclear weapons grade plutonium. In the 1950s, Pu-238 was found to be an effective fuel for robotic spacecraft that needed longer-lasting electrical power than what traditional chemical batteries could supply. Space science missions increasingly began using radioisotope power systems (RPS) that used Pu-238.

Currently, there is not a substitute power system for RPS. NASA had been designing an Advanced Stirling Radioisotope Generator, which would use less plutonium for less expensive planetary science missions, but they cancelled the program. Without RPS missions, and without a RPS substitute, there will be limited future planetary science missions.

A memorandum of understanding has existed between the Department of Energy (DOE) and NASA for the production of Pu-238 since the passage of the Atomic Energy Act in 1954. The Department of Energy has traditionally been responsible for the design, development, fabrication, evaluation, testing and delivery of Pu-238 to NASA. The National Space Policy issued in 2006 emphasizes DOE's role as manager of the nuclear infrastructure necessary for the production of Pu-238.[5] DOE had financial responsibility for the production facilities, and NASA has reimbursed DOE for the production cost of the Pu-238 NASA needed.[6]

In 1988, U.S. nuclear weapons production facilities were closed, ending the nation's ability to produce plutonium. At the time production ended, there was believed to be a large enough stockpile to support NASA's RPS missions through the early 2000s.[7] In 1992, the stockpile was supplemented by purchasing Pu-238 from Russia. Russia no longer produces Pu-238, and no other country appears to be producing it.[8]

Two upcoming flagship Planetary Science missions will require use of Pu-238: the Mars 2020 Rover and a possible mission to Europa. Jim Green has said that NASA has only enough Pu-238 available for NASA's Mars Rover 2020 mission.[9]

According to NASA, at this time the United States has 17 kg of Pu-238 remaining for use in NASA RPS missions. Based on their calculations the Mars 2020 mission will use 4 kg and the Europa mission would use 13 kg. More Pu-238 would be needed for any RPS missions beyond Europa.[10]

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[5] http://www.whitehouse.gov/sites/default/files/microsites/ostp/national-space-policy-2006.pdf

[6] Ibid.

[7] National Research Council. *Radioisotope Power Systems: An Imperative for Maintaining U.S. Leadership in Space Exploration*. Washington, DC: The National Academies Press, 2009.

[8] The European Space Agency (ESA) does not use nuclear powered planetary science missions, because the EU does not produce Pu-238. Their Mars rover, for instance, is solar powered.

[9] http://www.spacenews.com/article/civil-space/39846nuclear-power-sources-nixed-for-nasa%E2%80%99s-next-discovery-mission

[10] Jim Green, NASA Planetary Science Division Director, NASA Mars Briefing for Committee staff, September 2, 2014. Dr. Green also informed Committee staff that research was being conducted to see if a solar powered Europa mission was feasible.

In 2013, NASA entered into an agreement with DOE to begin producing more Pu-238. The Pu-238 will be generated at Oak Ridge National Laboratory in Tennessee and stored at Idaho National Laboratory in Idaho. The pellets needed for the RPS will be produced at Los Alamos Lab in Las Alamos, NM.

The production facilities are in need of significant updating before production of Pu-238 can begin (some of the press machines required to make pellets are 50 years old). NASA has been paying DOE $50 million per year to upgrade and repair the production facilities, even though such upgrades and repair are the responsibility of the DOE according to the National Space Policy.

NASA has said that if production plans proceed as anticipated, they will be able to generate 1.5 kg of Pu-238 per year. In order to temper the hotter, new Pu-238 so that it meets the temperature requirements for RPS missions (too hot will melt the containment casing, while too cool will not provide the power needed), the newly generated Pu-238 will be blended with the older, cooler stockpile to achieve the optimal temperature.[11]

Congress has yet to receive a detailed plan from NASA outlining its agreement with DOE and how much Pu-238 it expects to need in coming decades. In a *Space News* article published in March 2014, NASA was quoted as saying that "there will not be enough plutonium-238 ready at the end of the decade to fuel comparatively inefficient Multi-Mission Radioisotope Thermoelectric Generators for both the Mars 2020 rover and the Discovery 13 mission." In the same article Jim Green was quoted in a NASA Advisory Council Planetary Science Subcommittee meeting as saying, "It will take approximately three-and-a-half years to replace that fully and get into production of the pellets." Once the pellets are produced, priority will be given to the Mars 2020 mission.[12] For the first time, a Planetary Science Announcement of Opportunity for Discovery-class missions (cost-capped, more frequent, and smaller, science focused missions) has told scientists that they should not submit proposals that require a radioisotope power system.[13]

## **The American Space Technology for Exploring Resources Opportunities in Deep Space (ASTEROIDS) Act of 2014**

Advances in the commercial space industry have been accompanied by interest in exploring resources that exist in space, including on asteroids and the Moon. Private companies recognize the potential for finding and extracting rare minerals and water in asteroids, and how the ability to access and retrieve these minerals may reduce U.S. dependence on foreign countries to supply domestic demand.

At this time there is not a clear legal precedent for how these companies would claim ownership of resources extracted from asteroids. Companies and policy makers are

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[11] Ibid.

[12] http://www.spacenews.com/article/civil-space/39846nuclear-power-sources-nixed-for-nasa%E2%80%99s-next-discovery-mission

[13] https://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=422861/solicitationId=%7BE688B67C-F571-CD88-D577-5DBEE9C425F6%7D/viewSolicitationDocument=1/Discovery2014draftAOFINAL.pdf

examining precedents established in legislation and treaties that may or may not be applicable to mining asteroids, such as:

- The General Mining Act of 1872 authorized and governed mining claims made on federal lands.
- The Convention of the Law of the Sea governs resource collection in international waters.[14]
- Article 2 of The Outer Space Treaty of 1967, which prohibits nuclear weapons in orbit around the Earth, on the Moon, or other celestial bodies; establishes that the purposes of space exploration shall be peaceful; forbids any government from claiming moons or planets as sovereign property; and stipulates that said bodies are the "common heritage of mankind."
- Precedents established in the development of the oil and gas industry are also being examined.

The ASTEROIDS Act of 2014 expresses the desire of commercial and private entities in this burgeoning industry to address the challenges of staking claims to resources in outer space. Without a guarantee of property rights to minerals extracted from an asteroid (not rights to ownership of an asteroid), there is no incentive for these companies to engage in this activity.

## Section by Section Analysis of the ASTEROIDS Act

**Section 1: Short Title**
The American Space Technology for Exploring Resource Opportunities in Deep Space Act

**Section 2: Title 51 Amendment**
Amends Title 51, "National and Commercial Space Programs," Subtitle V, "Programs Targeting Commercial Opportunities," by adding a new Chapter 51: "Asteroids Resource Exploration and Utilization."

**Section 51301: Commercialization of asteroid resource exploration and utilization in outer space**
This section directs the President to coordinate appropriate agencies to promote the development of a commercial asteroid industry, within the context of U.S. treaties. Specifically, it directs the President, through the FAA and other appropriate Federal agencies, to:

1. Facilitate the commercial exploration and utilization of asteroid resources to meet national needs;
2. Discourage government barriers to the development of safe and economically viable industries for exploration and utilization of asteroid resources, consistent with the Nation's international obligations;

[14] See specifically Part XI: http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

3. Promote the right of U.S. commercial entities to conduct these activities free of harmful interference and consistent with the Nation's international obligations; and
4. Develop the frameworks necessary to meet the Nation's international obligations.

**Section 51302: Legal framework**

a. Property Rights. – Recognizes that any resources obtained in outer space from an asteroid are the property of the entity that obtained them, and that such entity is entitled to all associated property rights.
b. Freedom from Harmful Interference. – Recognizes that an entity over which the U.S. has jurisdiction may assert a right to execute specific asteroid-related activities and that such an assertion will prevail if it is found to be first in time, derived upon a reasonable basis, and consistent with U.S. international obligations.
c. Safety of Operations. – Requires U.S. commercial asteroid utilization entities to avoid harmful interference with other spacecraft.
d. Relief from Harmful Interference. – Provides U.S. commercial asteroid utilization entities with a right of action against other private entities for harmful interference.
e. Exclusive Jurisdiction. – Provides for U.S. district courts to have exclusive jurisdiction over harmful interference claims, regardless of the amount in controversy.

**Section 51303: Definitions**

1. Defines "State"
2. Defines "United States commercial asteroid utilization entity" as "a person or company providing asteroid exploration or utilizations services" that is not controlled by a government and is (a) duly organized under the laws of the State; (b) subject to U.S. jurisdiction; or (c) a foreign entity that has voluntarily submitted to U.S. jurisdiction.