Statement of
Dr. John Grunsfeld
Associate Administrator, Science Mission Directorate
National Aeronautics and Space Administration

before the

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

Chairman Smith, Ranking Member Johnson and Members of the Committee, thank you for the opportunity to appear today to discuss recent discoveries in the exploration of our solar system as well as the future of NASA's Planetary Science program and our missions. For decades, NASA has extended US leadership in planetary exploration with increasingly capable missions and has produced a series of exciting achievements in planetary science.

Two weeks ago, on July 14th, NASA's New Horizons spacecraft made an historic flyby through the Pluto system, providing high-resolution images and other science observations from this first visit to Pluto and its moons. This capstone event celebrates the fact that in the last 50 years the U.S. has been the first to visit each of the planets, and now the dwarf planet Pluto in our solar system. We now have close-up views of this enigmatic object and its moons that are already testing our ideas about the formation of our solar system. We have known about Pluto now for over 85 years, since the discovery by American astronomer Clyde Tombaugh, but even observations with the venerable Hubble Space Telescope revealed only rough details. Like the explorers of the classic era, the NASA New Horizons mission captured previously unseen vistas allowing us to make the first maps of Pluto and its moons. Now, as New Horizons speeds off beyond Pluto, it is entering a new realm of the solar system, the Kuiper Belt. I look forward to Dr. Stern's testimony in which he will provide additional details about the New Horizons mission.

From the sun, which provides the warmth and energy that allows the Earth to be a habitable planet, to Mercury, Venus, the Earth, Mars, the main asteroid belt, Jupiter, Saturn, Uranus, Neptune, Pluto, and even into interstellar space, NASA space probes have been humanity's pathfinders and explorers in the depths of our solar system. We study the planets in our solar system to answer fundamental question about where we come from, how the solar system came to be, and in the search for life beyond the Earth. Space exploration is difficult, requiring our best and brightest engineers and scientists to succeed, and when we develop innovative probes to explore the solar system, we invent technologies which improve our lives here on planet Earth.

We continue to study our sun, the central driver of much of what we see in the solar system. Our STEREO spacecraft orbit the sun providing unmatched views, the Solar Dynamics Observatory continues to return amazing detail on a near real-time basis, the

Voyager 1 spacecraft continues to provide us with data from interstellar space and Voyager 2 from a far region of our solar system, and we are preparing to launch the Solar Probe Plus and Solar Orbiter in 2018.

NASA's MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft has changed our understanding of the planet Mercury. Although Mercury is one of Earth's nearest planetary neighbors, little was known about the planet prior to the MESSENGER mission. Among its many accomplishments after entering Mercury's orbit in 2011, the MESSENGER mission determined Mercury's surface composition, revealed its geological history and confirmed its internal magnetic field is offset from the planet's center. One key science finding of the mission provided compelling support for the long-held hypothesis that Mercury harbors abundant water ice and other volatile materials in its permanently shadowed polar craters. Data indicated the ice in Mercury's polar regions, if spread over an area the size of Washington, D.C., would be more than two miles thick. For the first time, scientists began seeing clearly a chapter in the story of how the inner planets, including Earth, acquired water and some of the chemical building blocks for life. A dark layer covering most of the water ice deposits supports the theory that organic compounds, as well as water, were delivered from the outer solar system to the inner planets and their delivery may have led to prebiotic chemical synthesis and thus to life on Earth.

Originally planned to orbit Mercury for one year, the mission exceeded all expectations, lasting for over four years and acquiring extensive datasets with its seven scientific instruments and radio science investigation. On April 30th, however, the spacecraft expended all of its fuel and impacted Mercury's surface. Given the incredible science returns thus far, we look forward to future discoveries through analysis of the data and images gathered by the MESSENGER mission during its lifetime.

At Mars, we have several missions in operation with more in development. The current Mars portfolio includes the *Curiosity* and *Opportunity* rovers, the Mars Reconnaissance Orbiter, the Mars Odyssey orbiter, and our collaboration with the European Space Agency's (ESA) Mars Express orbiter. These missions have already shown us a highly evolved dynamic planet that once could have supported microbial life and has the potential to support humans in the future. The mission portfolio also includes the Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter, which arrived at the Red Planet last year to study the history of Mars' atmosphere and climate, liquid water and planetary habitability. Building on the success of these operating missions, NASA's Planetary Science program will continue its strategic, multi-mission approach to thoroughly investigating Mars.

Future missions to Mars include the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission, which will launch and land in 2016, providing our first look into the deep interior of Mars; participation on ESA's 2016 and 2018 ExoMars missions; and the new NASA Mars rover planned for launch in 2020. In particular, the Mars 2020 rover will carry seven instruments to conduct geological assessments of the rover's landing site, determine the potential habitability of the environment, directly search for signs of ancient Martian life and for the first time, collect high-grade samples for potential future return to Earth. Furthermore, the Mars 2020 mission will help advance our knowledge of how we may achieve the ultimate goal of landing humans on Mars. The Mars 2020 heat shield will include instruments that collect data during descent through the Martian atmosphere to inform designers of future landing systems. Once on the surface, the rover will also carry an experimental payload to demonstrate technology to process carbon dioxide from the atmosphere to produce oxygen – a method that could one day be used to produce oxygen for rocket propellant.

Beyond Mars is the main asteroid belt; there NASA's Dawn mission is currently studying the dwarf planet, Ceres, which is the largest object in the main asteroid belt. Previously, the Dawn mission explored the giant asteroid Vesta for 14 months from 2011 to 2012. Dawn has the distinction of being the first spacecraft to orbit a dwarf planet and the only spacecraft to orbit two extraterrestrial targets.

After arriving at Ceres in March of this year, Dawn began returning a wealth of photographs and other scientific measurements to help characterize and investigate the dwarf planet. Most notably, Dawn has captured a sequence of images that showcase a group of bright spots on Ceres, which scientists have concluded are caused by the reflection of sunlight by material on the surface. Dawn's visible and infrared mapping spectrometer allows scientists to identify specific minerals present on Ceres by looking at how light is reflected. Each mineral reflects the range of visible and infrared-light wavelengths in a unique way, and this signature helps scientists determine the components of Ceres. As the spacecraft continues to send back additional images and data, scientists will learn more about the mysterious bright spots.

In addition to the bright spots, Dawn's view from its present altitude has included a wide range of other intriguing sights, including craters, canyons and mountainous regions. There is also ample evidence of past activity on the surface, including flows, landslides and collapsed structures. With two very successful mapping campaigns complete, Dawn's next priority is to work its way down through Ceres' gravitational field to maneuver to a circular orbit three times as close to the dwarf planet as it is now, to an altitude of about 900 miles (less than 1,500 kilometers) for additional investigations. I look forward to Dr. Russell's testimony which will provide additional details about the Dawn mission.

As demonstrated by Dawn's extensive study of Vesta, asteroids and other small bodies continue to be objects of importance for NASA to study. Examination of these objects allows scientists to investigate how planets formed and how life began and improves our understanding of asteroids that could impact Earth. For example, NASA is currently developing a robotic asteroid rendezvous and sample return mission, dubbed OSIRIS-REx (for Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer), which is planned to launch next year. The first U.S. mission of its kind, OSIRIS-REx will approach the near-Earth Asteroid 1999 RQ36 (Bennu), map the asteroid, and collect a sample of as much as 1.2 kg for return to Earth in 2023. In addition, NASA restarted the Wide-field Infrared Survey Explorer (now called

NEOWISE) to collect data on near-Earth objects (NEO) over a three year study – which will end next year – and provide us the clearest picture yet of the NEOs that pose impact hazards to our planet. Currently, NEOWISE has made more than 264,000 infrared measurements of 13,522 solar system objects, including 348 NEOs and 66 comets.

SMD's Near Earth Object (NEO) Program is also using its extensive ground and space observatory network to help find suitable asteroid candidates for NASA's Asteroid Redirect Mission (ARM) – a robotic mission aimed to visit a large near-Earth asteroid, collect a multi-ton boulder from its surface, and redirect it into a stable orbit around the moon for astronauts to explore. While not specifically a science mission, ARM is a cost effective mission in the mid-2020s, which complements well the learning on the International Space Station and provides cross-directorate research and technology development through NASA's Human Exploration and Operations, Science and Space Technology Mission Directorates. In particular, potential candidates for ARM are just a subset of the population of near-Earth asteroids that the Science Mission Directorate's NEO Program seeks to find in its primary mission. As our surveys find asteroids that might make good candidates for ARM, we further characterize the object for our own NEO Program interests as well as for potential destinations for robotic or human spaceflight missions.

On the way to Jupiter is our Juno mission, which will arrive next year at the biggest planet in our solar system. The mission will hopefully reveal our largest planet's composition; whether there exists a solid core; how deep Jupiter's atmospheric zones, belts, and other features penetrate; how far reaching and intense is its magnetic field; and how much water and ammonia exists in its atmosphere.

Jupiter is host to a collection of amazing moons, several of which are larger than our own moon. One of the most fascinating of Jupiter's moons is Europa, which is believed to harbor a salty ocean underneath a thick crust of ice. This enigmatic body holds the potential to harbor life in its ocean. NASA is working on a mission that will send a highly capable, radiation-tolerant spacecraft into a long, looping orbit around Jupiter to perform repeated close flybys of the giant planet's moon. The goal will be to conduct detailed reconnaissance of Europa and to answer the big question, "Is Europa habitable?"

Last year, NASA invited researchers to submit proposals for instruments to study Europa. Thirty-three were reviewed and nine were selected this past May for a mission that will launch in the mid-to-late 2020s. The payload of selected science instruments includes cameras and spectrometers to produce high-resolution images of Europa's surface and determine its composition, while an ice-penetrating radar will determine the thickness of the moon's icy shell and search for subsurface lakes similar to those beneath Antarctica. The mission also will carry a magnetometer to measure strength and direction of the moon's magnetic field, which will allow scientists to determine the depth and salinity of its ocean. A thermal instrument will scour Europa's frozen surface in search of recent eruptions of warmer water, while additional instruments will search for evidence of water and tiny particles in the Europa's thin atmosphere. I look forward to Dr. Pappalrdo's testimony which will provide additional details about our planned Europa mission.

Further out at Saturn, Cassini continues to bring us valuable discoveries in the Saturn system, providing what can only be described as some of the most vivid and captivating images ever taken in our solar system. Recently, the Cassini spacecraft observed the small moon Enceladus emitting sheets of water from features on the surface. These water plumes may well indicate that under the icy crust of Enceladus there are subsurface lakes, created by tidal heating. These subsurface lakes could represent safe harbors for microbial life. In 2017, the Cassini mission will be sent on a new mission, as it runs out of fuel, to orbit inside of the rings and plunge into the Saturnian atmosphere, taking data on the way in; a dramatic and fitting end for a transformative planetary explorer.

While we have no current plans for a revisit to Uranus and Neptune, following on the grand tour of Voyager 2 in the late 1980s, the James Webb Space Telescope promises to provide extraordinary science by observing these giant icy planets in unparalleled spectroscopic detail.

And while New Horizons has already provided exciting views of the dwarf planet Pluto and its moons, the mission will also venture deeper into the distant Kuiper Belt, initiating exploration of a relic of solar system formation that comprises many Pluto-like objects. These observations will be critical to our understanding of this distant and so far unexplored outer region of our solar system. And still further out, Voyager 1 and 2 continue to operate as part of the Voyager Interstellar Mission. These two aging, but still capable, explorers continue to study the outer heliosphere, the heliosheath and now the interstellar medium with plasma, energetic particle, magnetic field and plasma wave instruments. Among them, the two Voyagers hold records as the longest-operating and the most distant spacecraft ever built by humankind.

Conclusion

The United States has been the first nation successfully to reach every planet from Mercury to Pluto with a space probe, but our study of the solar system does not stop at the Voyagers or New Horizons. We continue to seek answers to fundamental science questions, including whether we are alone in the universe. NASA will probe deeper into this question by studying solar systems around *other* stars (exoplanets) using Hubble, Spitzer, Kepler, the Transiting Exoplanet Survey Satellite (TESS) that will launch in 2018, and ground-based telescopes. We eagerly await the James Webb Space Telescope and its potential to transform this field. This great journey into the unknown continues and there is still much to be learned. With your support, our future missions will advance along this path of exploration, discovery and innovation for generations to come.

Again, thank you for the opportunity to testify today and I look forward to responding to any questions you may have.