CURATING NASA'S EXTRATERRESTRIAL SAMPLES

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Curating NASA's Extraterrestrial Samples

— Carlton Allen and the Astromaterials Curation Team, NASA Johnson Space Center

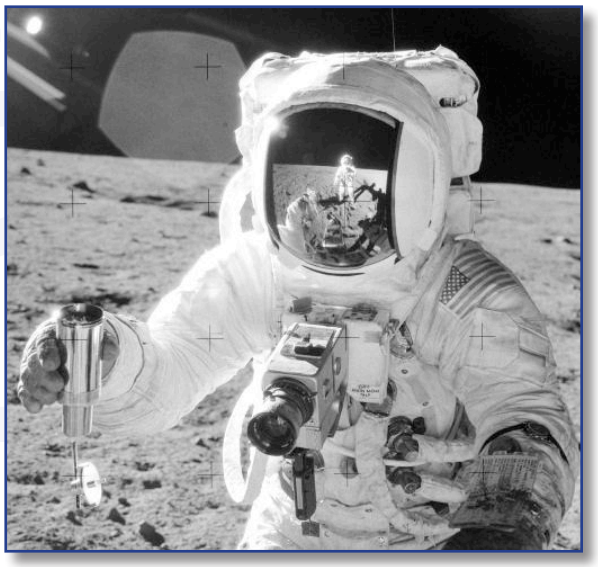
Note from the Editors: This article is the second in a series of reports describing the history and current activities of NASA's planetary research facilities worldwide. — Paul Schenk and Renée Dotson

Rock and dust samples from many solar system objects have made their way to Earth, either via spacecraft missions (manned and unmanned), or by simply falling to Earth's surface from deep space. Curation of such extraterrestrial samples is the critical interface between sample return missions and the international research community. Curation includes documentation, preservation, physical security, preparation, and allocation of samples for research, education, and public outreach.

The NASA Johnson Space Center (JSC) in Houston, Texas, is responsible for curating NASA's seven collections of extraterrestrial samples. These collections comprise lunar rocks and soils collected by the Apollo astronauts, meteorites collected in Antarctica, cosmic dust collected by aircraft, solar wind atoms collected by the Genesis spacecraft, comet particles collected by the Stardust spacecraft, interstellar dust particles collected by Stardust, and asteroid surface particles collected by the Hayabusa spacecraft.

The curators of these collections have developed specialized laboratories and procedures to preserve and protect the samples, meet current research needs, and support studies into the indefinite future. This suite of laboratories is unique in the world. A subset of each collection is maintained at a secure facility remote from JSC, ensuring that entire collections are not lost in the event of a disaster.

Instructions for requesting samples, as well as catalogs, newsletters, images, and research results, are available online at *curator.jsc.nasa.gov*. The increasing demand for extraterrestrial samples — resulting in more than 1500 total allocations in 2013 — reflects the fact that careful curation can lead to important research, even decades after samples are collected.



Apollo astronaut collecting soil sample (NASA photo AS 12-49-7278). Credit: NASA.

Lunar Rocks and Soils —

Between 1969 and 1972, the Apollo astronauts collected 2196 individual rock, soil, and core samples, with a total mass of 382 kilograms (842 pounds). The samples are stored in positive-pressure nitrogen glove boxes in cleanroom laboratories, and are only in contact with precision-cleaned tools and containers. Approximately 10% of the total mass of the collection has been allocated for research, including portions of nearly every individual sample. A total of five vacuum containers and regolith core sections have never been opened since they were collected more than 40 years ago.

Study of the Apollo samples continues to yield information about the early history of the Moon, Earth, and the inner solar system. Computer models

Martian meteorite Miller Range (MIL) 03346 in Antarctica; centimeter scale. Credit: ANSMET/Case Western Reserve University.

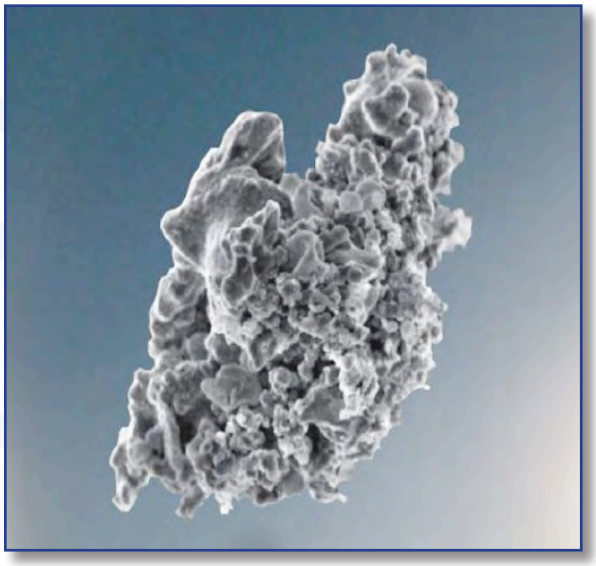
indicate that the Moon could have been formed from the debris produced when Earth was struck by a planetary body about the size of Mars. The chemical composition of the Moon, derived from studies of lunar rocks, supports this theory of origin. Formation of the lunar crust, the intense meteorite bombardment occurring afterward, subsequent lava outpourings, and the continuing impact of micrometeorites are all recorded in these samples.

Antarctic Meteorites —

Meteorites fall randomly, but the best place to systematically collect them is Antarctica. The movement and sublimation of glaciers lead to natural concentrations of meteorites in specific areas of ice. Furthermore, dark meteorites are easy to pick out on the white background of ice.

The Antarctic Search for Meteorites (ANSMET) program, a collaboration between NASA, the U.S. National Science Foundation (NSF), and the Smithsonian Institution, uses these advantages to help gather samples. NSF provides support for field collection. NASA provides classification, storage, and distribution; after initial processing, some samples get shipped to the Smithsonian Institution to reside in a national museum archive. Over more than 30 years, the ANSMET program has recovered more than 20,000 samples. These meteorites are shipped frozen to JSC, thawed in a nitrogen cabinet to remove ice or water, and stored in a cleanroom laboratory in a controlled atmosphere of either air or nitrogen.

The Antarctic meteorite collection is diverse and provides constraints on stellar formation and nucleosynthesis through studies of presolar grains, the age and chemical evolution of the solar system, the timing and extent of differentiation, and the possible widespread bombardment initiated by outer planet dynamics (also known as the late heavy bombardment). Most meteorites are from asteroids, including many from Vesta, although 24 ANSMET meteorites are currently known to be from the Moon and 12 from Mars, based on their spectroscopy, petrology, and geochemistry.



Scanning electron micrograph of an anhydrous chondritic porous interplanetary cosmic dust particle 8 micrometers in length. Credit: NASA/Scott Messenger.

Cosmic Dust —

Tons of cosmic dust grains, including samples from asteroids and comets, fall from space each year. Many of these microscopic particles decelerate and settle through the atmosphere. They are collected at altitudes around 20 kilometers by NASA WB-57 and ER-2 aircraft using Lexan plates, coated with

silicone oil. The collectors are transferred to the Cosmic Dust Laboratory at JSC. Particles are removed and imaged by scanning electron microscopy, and then have their elemental abundances determined by energy-dispersive X-ray analysis. Particular efforts have been made to fly collectors at times of enhanced contributions from specific comets.

The cosmic dust collection includes particles that are in nearly the same condition as when the solar system began to form. Microanalysis has also identified particles with compositions consistent with an origin in interstellar molecular clouds and high-temperature condensates that may have formed in the early solar system, in the outflow of other stars, or in supernova explosions.

Solar Wind Atoms from the Genesis Spacecraft —

The Genesis spacecraft collected samples of the solar wind — the dilute stream of ions continually ejected from the Sun. Solar wind was captured at the Earth-Sun Lagrangian (L1) point using high-purity collectors over 28 months. The Genesis capsule returned to Earth in 2004. Following reentry, the parachutes failed to deploy and the capsule impacted the landing site — in the Utah Test and Training Range (UTTR) — at a speed of more than 86 meters per second (192 miles per hour). Using preestablished contingency procedures, thousands of spacecraft parts and collector fragments were recovered and transported to the Genesis Curation Laboratory at JSC. The science team and curators have devoted extensive effort to identifying, cleaning, assessing, and cataloging thousands of collector fragments to make them available for analysis. Thanks to their work, most of the original 20 Genesis mission objectives were met or are currently the subject of active research.

JSC curator preparing a sample in the Genesis Laboratory. Credit: NASA

The highest priority of the mission was to accurately and precisely determine the isotopic composition of oxygen in the Sun. Genesis sample measurements demonstrate that Earth is highly depleted in oxygen-16 (^{16}O) relative to the Sun and the bulk starting composition of the solar system. This is a key example of Genesis data — despite the crash — revealing information about processes and conditions in early solar system history.

Scientists preparing samples in the Stardust Laboratory. Credit: NASA-JSC.

Comet Particles from the Stardust Spacecraft — Stardust was the first mission to return samples from a comet. The spacecraft was launched in 1999 and successfully encountered Comet Wild-2 in 2004. As the spacecraft passed through the comet's coma, a tray of silica aerogel blocks captured several thousand dust grains. The encounter velocity was 6.1 kilometers per second (13,650 miles per hour), fast enough to embed comet particles into the aerogel but insufficient to completely destroy them.

The sample return capsule parachuted to Earth at UTTR in 2006 and was flown to the Stardust Laboratory at JSC. Samples were placed in precision-cleaned quartz-glass containers and stored under high-purity nitrogen gas. Samples currently available include naked grains, microtomed slices and portions of epoxy-embedded grains, individual grains or grain tracks enclosed within small bits of aerogel, and — in exceptional circumstances — entire aerogel blocks.

Ongoing analysis of the Stardust samples, combined with spacecraft and groundbased comet observations, continues to yield new insights into the formation and early history of our solar system. Comets are ancient, diverse objects that contain material from throughout the accretionary disk from which the planets formed. Precise analyses of single comet particles can strongly constrain the chemistry and timescale of solar system formation. The discovery of cometary amines in Stardust material supports the hypothesis that comets were an important source of prebiotic organic carbon and nitrogen on the early Earth.

Interstellar Dust Particles from Stardust — The Stardust spacecraft also carried a collector dedicated to the capture of contemporary interstellar dust. This collector was exposed to the interstellar dust stream for a total of 196 days at heliocentric distances of 2.0–2.5 astronomical units (AU).

Compared to comet particles, the interstellar particles were expected to be three orders of magnitude smaller in both their mass and fluence. Simply finding this small number of tiny particles in the aerogel was recognized by Stardust investigators as a major technical challenge. Optical scanning at the magnification required to identify the particle tracks required examination of millions of fields of view. A citizen science strategy was developed, using approximately 30,000 volunteers who completed rigorous online training, to examine sets of through-focus photomicrographs generated in the JSC Curation Laboratories. Currently, more than 1.5 million images have been posted online at *stardustathome.ssl.berkeley.edu*. Participants in this Stardust@home program have identified several potential interstellar grains. Following preliminary examination, materials from the Stardust interstellar tray are being made available to the international research community for detailed analyses.

Hayabusa Asteroid Samples —
The Japan Aerospace Exploration Agency (JAXA) launched the Hayabusa spacecraft in 2003 to rendezvous with asteroid Itokawa and return surface samples to Earth. Hayabusa reached the asteroid in 2005 and made several attempts to collect samples by firing metal projectiles into the asteroid's surface. Although the sampling mechanism did not work as intended, thousands of particles up to 300 micrometers in diameter were found sealed in the sample containers, apparently collected during spacecraft touchdowns onto the surface of the asteroid. Following a harrowing series of propulsion, communication, and control failures, the spacecraft returned to Earth in 2010 and was recovered in the Woomera Prohibited Area of Australia. JAXA agreed to transfer 10% of the Hayabusa samples to NASA JSC, where they are curated in sealed containers that are housed under nitrogen in a stainless steel glove box. Requests for Hayabusa samples can be made through both the JSC Curator's website and JAXA.

Analyses of Hayabusa samples have verified the connection between primitive meteorites and stony (S-type) asteroids. The samples also serve as a benchmark for the physical and optical effects of space weathering — the combination of solar and cosmic irradiation and micrometeorite bombardment — that alters the surfaces of solar system objects without atmospheres. These first *in situ* samples of an asteroidal surface provide ground truth for the understanding of small bodies and microgravity environments throughout the solar system.

The Future: New Missions and Old Samples —
In 2011, NASA selected the Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) mission, designed to return samples from a C-class asteroid in 2023. JAXA is planning to sample another C-class asteroid with the Hayabusa-2 mission. The U.S. National Research Council's Planetary Decadal Survey listed the first lander in a Mars sample return campaign as one of its highest-priority flagship-class missions, with sample return from the lunar South Pole-Aitken basin and the surface of a comet among additional top priorities. Sample curators are deeply involved in planning how to meet the specific requirements of these future missions.

Nondestructive methods of examination have the potential to increase the research return from samples already on Earth. The curators are investigating the potential of X-ray tomography to locate rare clasts in lunar breccia samples, as well as the possibility of using X-ray fluorescence and Raman mapping to highlight zircons and other important trace minerals within lunar rocks and meteorites. The last unopened Apollo vacuum containers and core segments may prove important to the study of lunar volatiles, and planning is underway on the optimum way to probe these unique samples.

Lessons Learned from More Than 40 Years of Curating Extraterrestrial Samples —
Through nearly a half century of work on analyzing and curating samples from places beyond Earth, a few key messages stand out. First and foremost, the main point of any sample return mission is laboratory analysis. Everything must be designed, built, and operated to get the highest-quality samples to the best laboratories.

Furthermore, curation begins with mission design. Samples will never be any cleaner than the tools and containers used to collect, transport, and store them. Scientists and engineers must be prepared in case missions don't go according to plan. Really bad things can, and do, happen to missions and to samples.

Careful planning and dedicated people can sometimes save the day, recover the samples, and preserve the science of the mission.

Every sample set is unique. Laboratories and operations must respond to the diversity and special requirements of the samples. Curating Moon rocks is far different from curating comet dust or solar wind atoms, for example.

Finally, curation means that those involved are in it for the long haul. Samples collected decades ago are yielding new discoveries that alter scientific understanding of planets, moons, and solar system history. These discoveries will inspire new generations of scientists and research questions, and will drive future exploration by robots and humans. Curation is — and will remain — the critical interface between collecting samples and the research that leads to understanding other worlds.

Additional Reading —

Allen C., Allton J., Lofgren G., Righter K., Zeigler R., and Zolensky M. (2013) Curating NASA's extraterrestrial samples. *EOS Trans. AGU, 94*, 253–254.

About the Cover—

Top: Image of Draconid meteors streaking through the sky during a meteor shower. NASA JSC's Cosmic Dust Collection Program has made special attempts to collect dust from particular meteor showers and asteroid families when flights can be planned well in advance, and very occasionally on short notice. In late October 2012, large- and small-area dust collectors were flown through the Draconid meteor storm on a NASA ER2 aircraft. Draconids, originating from Comet Giacobini-Zinner, have one of the slowest atmospheric entry velocities, and thus offer significant possibilities of successful dust capture in the stratosphere.

Inset left: In this artist's rendition, Hayabusa's sample collection horn touches the surface of asteroid Itokawa. The entire sample collection process only took one second. The Hayabusa mission marked the first time a spacecraft was able to retrieve a sample from an asteroid and return it to Earth. Credit: NASA JPL-Caltech/Artist Corby Waste.

Inset upper right: Apollo 15 sample 15556, a 1.5-kilogram rock, was plucked from near the rim of Hadley Rille at the Apollo 15 site. From the rim of Hadley, astronauts could see layers of basalt exposed in the wall of the rille, which is interpreted as an ancient lava channel. This medium-grained, extremely vesicular basalt is 3.4 billion years old. Since the Moon is very dry, the volatile gas causing the vesicles (bubble cavities) in this rock and other rocks probably was a mix of oxides of carbon and sulfur dissolved in the molten rock. Credit: NASA.

Inset lower right: A thin section of a meteorite from the Miller Range, Antarctica, looks a bit like a stained glass window. Credit: Tim McCoy.

About the Author:

Dr. Carlton Allen is the Astromaterials Curator and Manager of the Astromaterials Acquisition and Curation Office at the NASA Johnson Space Center. Allen earned a Ph.D. in Planetary Sciences from the University of Arizona, studying the interactions between volcanos and ice on Earth and Mars. As a postdoctoral fellow at the University of New Mexico, he researched formation mechanisms for martian soil. Allen has studied the underground storage of high level nuclear waste and the extraction of oxygen from the soil and rock of the Moon, and has conducted field research in Hawaii, Canada, Mexico, and Iceland, as well as searched for meteorites in Antarctica. Allen's current research is split between studies of possible ancient habitats on Mars and the unique requirements of future sample return missions.

NASA Extends Moon Exploring Satellite Mission

This is an artist's depiction of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) observatory in space with the Moon in the distance. Credit: NASA Ames/Dana Berry.

NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) observatory was approved for a 28-day mission extension. The spacecraft is now expected to impact the lunar surface on or around April 21, 2014, depending on the final trajectory. The extension provides an opportunity for the satellite to gather an additional full lunar cycle worth of very low-altitude data to help scientists unravel the mysteries of the Moon's atmosphere.

"The launch vehicle performance and orbit capture burns using LADEE's onboard engines were extremely accurate, so the spacecraft had significant propellant remaining to enable extra science," said Butler Hine, LADEE project manager at NASA's Ames Research Center, where the mission was designed, built, tested and its day-to-day operations are managed. "This extension represents a tremendous increase in the amount of science data returned from the mission."

The small, car-sized robotic probe launched September 6, 2013, from NASA's Wallops Flight Facility, and has been orbiting the Moon since October 6. On November 10, LADEE began gathering science data and on November 20, the spacecraft entered its science orbit around the Moon's equator at an altitude of 8–37 miles (12–60 kilometers) above the surface, a unique position that allows the spacecraft to frequently pass from lunar day to lunar night, approximately every two hours. This vantage provides data about the full scope of changes and processes occurring within the Moon's tenuous atmosphere.

"The science team has already established a baseline of data for the tenuous lunar atmosphere, or exosphere, and dust impacts," said Rick Elphic, LADEE project scientist at Ames. "One cool thing about this extension is that we plan to fly LADEE at only a few kilometers above the lunar surface. This will be much lower than we've been before."

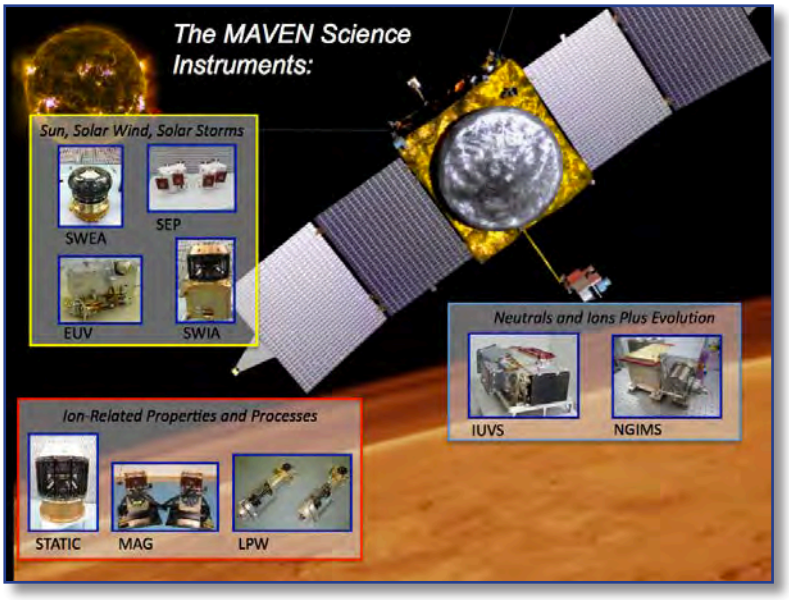
Using a set of three instruments, scientists are able to measure the chemical composition of the atmosphere, collect and analyze samples of lunar dust particles in the atmosphere, and hope to address a long-standing question: Was lunar dust, electrically charged by sunlight, responsible for the pre-sunrise glow above the lunar horizon detected during several Apollo missions? Specifically, the Neutral Mass Spectrometer operates while pointing in different directions to look for atoms and molecules in the lunar atmosphere from a variety of sources, and has measured helium, neon, and argon-40, three noble gases. The Ultraviolet-Visible Spectrometer has peered over the lunar horizon to look for the glow of atoms, molecules, and dust in the lunar atmosphere and has made measurements of atmospheric sodium and potassium at lunar sunset, sunrise, and noon. The Lunar Dust Experiment (LDEX) recorded dust impacts as soon as its cover opened and has measured the dust tossed up by a fairly steady "rain" of meteoroids on

the lunar surface. LDEX occasionally sees an increase in dust impacts due to meteoroid showers, such as the Geminids, and "dust bursts" that may be due to LADEE flying through plumes kicked up from nearby meteoroid impacts.

Detailed information about the structure and composition of the thin lunar atmosphere and whether dust is being lofted into the lunar sky will help researchers understand other bodies in the solar system, such as large asteroids, Mercury, and the moons of outer planets. For more information, visit *www.nasa.gov/ladee*.

MAVEN on Track to Carry Out Its Science Mission

The Mars Atmosphere and Volatile Evolution (MAVEN) mission is designed to explore Mars' upper atmosphere. It will determine the role that escape of gas from the atmosphere to space has played in changing the climate throughout the planet's history. MAVEN was launched on November 18, 2013, and will go into orbit around Mars on the evening of September 21, 2014. The MAVEN spacecraft and all of its science instruments have now completed their initial checkout, and all of them are working as expected. This means that MAVEN is on track to carry out its full science mission as originally planned.



MAVEN's three instrument packages provide the comprehensive measurements essential to understanding the evolution of the martian atmosphere over time. Credit: MAVEN.

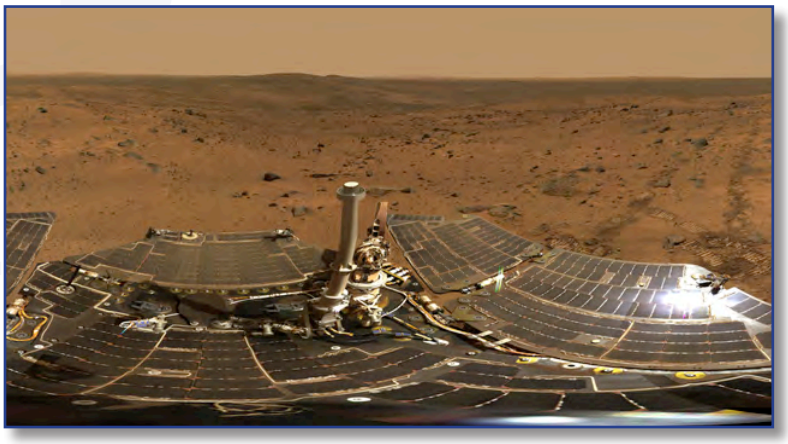
After a five-week commissioning phase in orbit, during which it will get into its science-mapping orbit, deploy its booms, and do a final checkout of the science instruments, it will carry out a one-Earth-year mission. It will observe the structure and composition of the upper atmosphere, determine the rate of escape of gas to space today and the processes controlling it, and make measurements that will allow it to determine the total amount of gas lost to space over time. "Successful checkout of the spacecraft and instruments is a major milestone in carrying out our mission," said Dr. Bruce Jakosky, MAVEN principal investigator from the University of Colorado in Boulder. "While there are still a lot of things that have to happen properly before we get to Mars and can do the mission's science, we are exactly where we need to be today."

Upcoming events in the next month include additional instrument testing and spacecraft calibrations, first testing of the Electra communications package that will be used to relay data from the rovers currently on the surface of Mars, and the second planned Trajectory Correction Maneuver. This maneuver will adjust the spacecraft's path by a very small amount so that it will be positioned properly for the rocket-motor burn that will put it into orbit when it arrives at Mars. "The performance of the spacecraft and instruments to date bears out all the hard work the team put into testing the system while it was on the ground," said

David Mitchell, MAVEN project manager at NASA's Goddard Space Flight Center. "The way that the operations team has performed while flying the system has been nothing short of outstanding. We have big events ahead of us before we can claim success but I am very pleased with how things have gone thus far."

MAVEN will travel about 442 million miles (712 million kilometers) on its path to Mars. MAVEN is currently traveling in its transfer orbit around the Sun at a speed of 69,480 miles per hour (31.06 kilometers per second). For more information, visit *lasp.colorado.edu/home/maven*.

NASA and Smithsonian Host 10-Year Mars Rover Events



This image taken by the panoramic camera on the Mars Exploration Rover Opportunity shows the view of Victoria Crater from Duck Bay. Opportunity reached Victoria Crater on Sol 951 (September 27, 2006) after traversing 9.28 kilometers (5.77 miles) since her landing site at Eagle Crater. Credit: NASA/JPL-Caltech/Cornell.

NASA and the Smithsonian National Air and Space Museum (NASM) in Washington sponsored events to commemorate 10 years of roving across the Red Planet by the Mars Exploration Rovers (MER). Anniversary activities will showcase the images and achievements of Spirit and Opportunity, both launched by NASA in the summer of 2003. Activities also will highlight how Mars robotic exploration and discovery will aid plans for a future human mission to Mars.

Spirit and Opportunity completed their three-month prime missions in April 2004 and went on to perform extended missions for years. The rovers made important discoveries about wet environments on ancient Mars that may have been favorable for supporting microbial life. Although Spirit ceased communicating with Earth in March 2010, the Opportunity rover continues its work on the Red Planet.

On January 7, NASA and the museum facilitated two panel discussions on Mars robotic and human missions. Held in the museum's Moving Beyond Earth gallery, participants discussed the MER program and its scientific successes. Participants also provided updates on the agency's activities to advance a human mission to Mars in the 2030s. The museum is also featuring a new exhibit, "Spirit and Opportunity: 10 Years Roving Across Mars," with more than 50 mosaic and panoramic photographs taken by the rovers. From a view of the Sun setting over the rim of a crater, to a study of "abstract dunes," to a shot of rover tracks disappearing over the horizon, the images were chosen for their scientific and aesthetic content by MER mission team members.

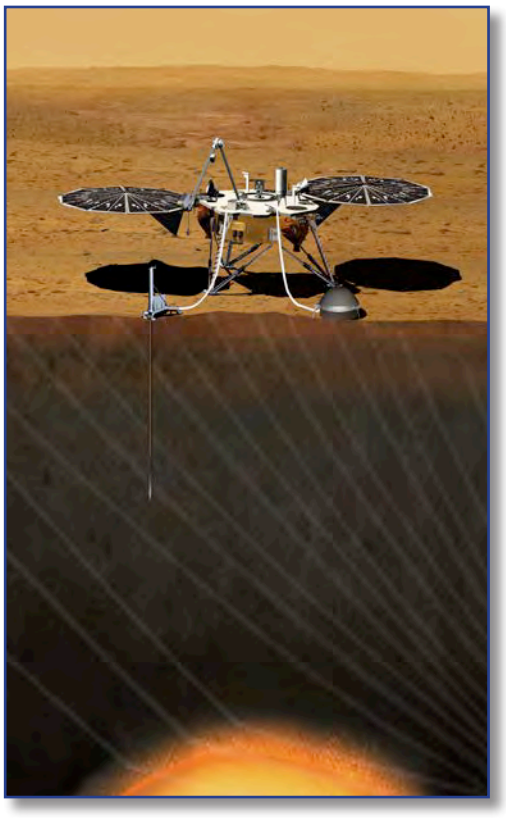
On Thursday, January 16, JPL hosted public celebration of a decade of the twin Mars Exploration rovers. The event was held in the Beckman Auditorium on the California Institute of Technology campus. Participants were Charles Elachi (JPL Director), Steve Squyres (professor of astronomy at Cornell

University and principal investigator for the Mars Exploration Rover mission), John Callas (project manager, Mars Exploration Rover Project), and Bill Nye (chief executive officer of the Planetary Society). On Friday, January 17, JPL hosted a public lecture delivered by John Callas, entitled "The Mars Exploration Rovers: A Decade of Exploration," at the Vosloh Forum on the campus of Pasadena City College.

On Thursday, January 23, JPL hosted a media briefing on the Opportunity rover's decade of exploration. NASA Television and the agency's website provided live coverage of the event, and reporters and the public were able to ask questions from NASA centers and via Twitter using the hashtag #10YrsOnMars. Participants included John Callas, Steve Squyres, and Ray Arvidson (Mars Exploration Rovers deputy principal investigator, Washington University in St. Louis, Missouri). For more information on the rovers and the Mars Exploration Program, visit *mars.jpl.nasa.gov*.

NASA and French Space Agency Sign Agreement for Mars Mission

NASA Administrator Charles Bolden and Jean-Yves Le Gall, president of the National Center of Space Studies of France (CNES), signed an implementing agreement on February 10 for cooperation on a future NASA Mars lander called the Interior Exploration Using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission. "This new agreement strengthens the partnership between NASA and CNES in planetary science research, and builds on more than 20 years of cooperation with CNES on Mars exploration," said Bolden. "The research generated by this collaborative mission will give our agencies more information about the early formation of Mars, which will help us understand more about how Earth evolved."



This artist's concept depicts the stationary NASA Mars lander known by the acronym InSight at work studying the interior of Mars. The InSight mission will investigate processes that formed and shaped Mars and help scientists better understand the evolution of our inner solar system's rocky planets, including Earth. Credit: NASA/JPL-Caltech.

The InSight mission currently is planned for launch in March 2016 and is scheduled to land on Mars six months later. Designed to study the planet's deep interior, the mission seeks to understand the evolutionary formation of rocky planets, including Earth. InSight also will investigate the dynamics of martian tectonic activity and meteorite impacts using CNES's Seismic Experiment for Interior Structure instrument (SEIS). SEIS will measure seismic waves traveling through the interior of Mars to determine its interior structure and composition, which will provide clues about the processes that shaped the planet during its earliest stages of formation.

Other partners working with CNES on the SEIS instrument include the German Aerospace Center, United Kingdom

Space Agency, Swiss Space Office (through the European Space Agency), and NASA. InSight's international science team is made up of researchers from Austria, Belgium, Canada, France, Germany, Japan, Poland, Spain, Switzerland, the United Kingdom, and the United States. For more information, visit *insight.jpl.nasa.gov.*

Through the Gap: Curiosity Mars Rover Crosses Dune

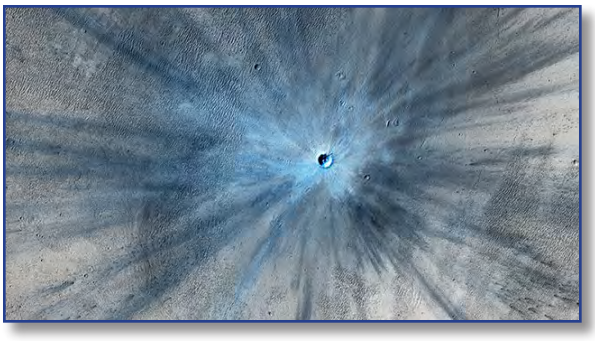
This view combines several frames taken by the Mast Camera (Mastcam) on NASA's Mars rover Curiosity, looking into a valley to the west from the eastern side of a dune at the eastern end of the valley. The team operating Curiosity has chosen this valley as a likely route toward mid-term and long-term science destinations. Credit: NASA/JPL-Caltech/MSSS.

NASA's Curiosity Mars rover has crossed a dune that stands across a gateway to a southwestward route favored by the rover team for driving to future science destinations. After reaching the west side of the 3-foot-tall (1-meter-tall) dune on February 6, the rover looked back at its tracks down the western slope. A raw image of the rover's tracks over the dune is available at *1.usa.gov/Mw9HmZ*.

The dune sits between low scarps at a site called "Dingo Gap" inside Mars' Gale Crater. Now that Curiosity has passed through the gap, engineers and scientists plan to direct the mobile laboratory toward a location of interest where different rock types intersect. That is a candidate site for next use of the rover's drill. Beyond that, the drive will continue toward the mission's long-term science destination on lower slopes of Mount Sharp, in the middle of the crater. The team operating NASA's Curiosity Mars rover will likely drive the rover westward over a dune and across a valley with fewer sharp rock hazards than alternative routes.

A final decision on whether to pass through this valley will ride on evaluation of a short drive planned this week toward the top of the dune that lies across "Dingo Gap." The dune is about 3 feet (1 meter) high at its center, tapered off at both sides of the gap between two low scarps. A color view assembled from images taken by Curiosity's Mast Camera (Mastcam) on the east side of the dune shows details of the valley that the rover may traverse this month. For more information about Curiosity, visit *www.nasa.gov/msl* and *mars.jpl.nasa.gov/msl*.

NASA Mars Orbiter Examines Dramatic New Crater

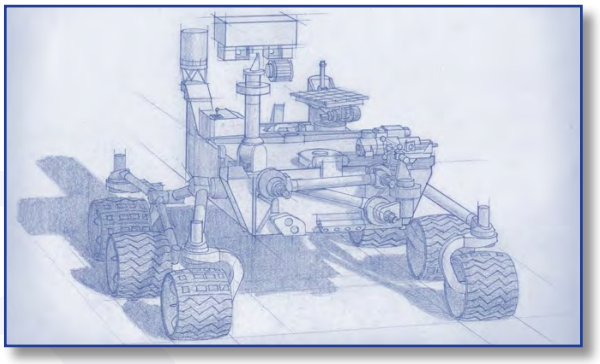


A dramatic, fresh impact crater dominates this image taken by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter on November 19, 2013. Researchers used HiRISE to examine this site because the orbiter's Context Camera had revealed a change in appearance here between observations in July 2010 and May 2012, bracketing the formation of the crater between those observations. Credit: NASA/JPL-Caltech/Univ. of Arizona.

Space rocks hitting Mars excavate fresh craters at a pace of more than 200 per year, but few new Mars scars pack as much visual punch as one seen in a NASA image released on February 5. The image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter shows a crater about 100 feet (30 meters) in diameter at the center of a radial burst painting the surface with a pattern of bright and dark tones. The image is available online at *uahirise.org/ESP_034285_1835*.

The scar appeared at some time between imaging of this location by the orbiter's Context Camera in July 2010 and again in May 2012. Based on apparent changes between those before-and-after images at lower resolution, researchers used HiRISE to acquire this new image on November 19, 2013. The impact that excavated this crater threw some material as far as 9.3 miles (15 kilometers).

For more information about the Mars Reconnaissance Orbiter, which has been studying Mars from orbit since 2006, visit *www.nasa.gov/mro*.



Planning for NASA's 2020 Mars rover envisions a basic structure that capitalizes on reusing the design and engineering work done for the NASA rover Curiosity. Credit: NASA/JPL-Caltech.

NASA Receives Mars 2020 Rover Instrument Proposals for Evaluation

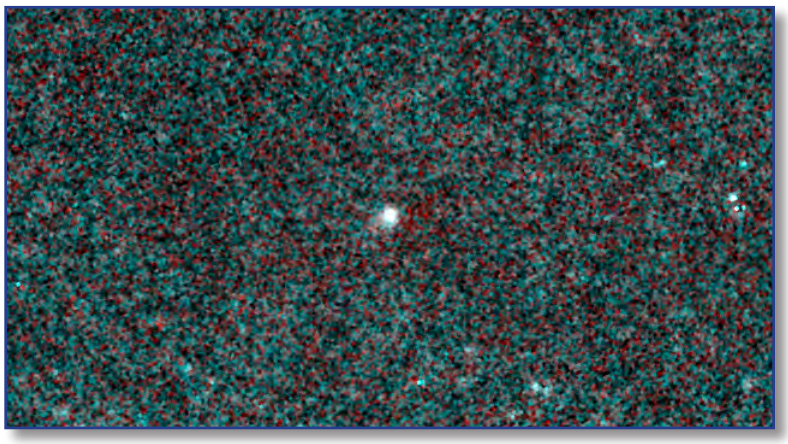
NASA has received 58 proposals for science and exploration technology instruments to fly onboard the agency's next Mars rover in 2020, twice the usual number submitted for instrument competitions in the recent past, and an indicator of the extraordinary interest in exploration of the Red Planet. The agency is beginning a thorough review to determine the best combination of science and exploration technology investigations for the mission and anticipates making final selections in the next five months.

"Proposal writing for science missions is extremely difficult and time consuming. We truly appreciate this overwhelming response by the worldwide science and technical community and are humbled by the support and enthusiasm for this unique mission," said John Grunsfeld, NASA's associate administrator for science in Washington. "We fully expect to be able to select an instrument suite that will return exciting science and advance space exploration at Mars." NASA opened competition for Mars 2020 research

proposals in September and closed it January 15. Several NASA facilities, academia, industry, research laboratories, and other government agencies submitted proposals. Seventeen proposals came from international partners.

The Mars 2020 mission is designed to accomplish several high-priority planetary science goals and will be an important step toward meeting President Obama's challenge to send humans to Mars in the 2030s. The mission will conduct geological assessments of the rover's landing site, determine the habitability of the environment, search for signs of ancient martian life, and assess natural resources and hazards for future human explorers. For more information, visit *mars.jpl.nasa.gov/mars2020*.

NASA Preparing for 2014 Comet Encounter with Mars



NASA's NEOWISE mission captured images of Comet C/2013 A1 Siding Spring, which is slated to make a close pass by Mars on October 19, 2014. The infrared pictures reveal a comet that is active and very dusty even though it was about 355 million miles (571 million kilometers) away from the Sun on January 16, 2014, when this picture was taken. Credit: NASA/JPL-Caltech.

This spring, NASA will be paying cautious attention to a comet that could put on a barnstorming show at Mars on October 19, 2014. On that date, Comet 2013 A1 Siding Spring will buzz Mars about 10 times closer than any identified comet has ever flown past Earth. Spacecraft at Mars might get a good look at the nucleus of Comet Siding Spring as it heads toward the closest approach, roughly 86,000 miles (138,000 kilometers) from the planet (give or take a few percent). On the other hand, dust particles that the comet nucleus sheds this spring could threaten orbiting spacecraft at Mars in October. The level of risk won't be known for months, but NASA is already evaluating possible precautionary measures as it prepares for studying the comet.

"Our plans for using spacecraft at Mars to observe Comet Siding Spring will be coordinated with plans for how the orbiters will duck and cover, if we need to do that," said Rich Zurek, Mars Exploration Program chief scientist at NASA's Jet Propulsion Laboratory.

Comet Siding Spring, formally named C/2013 A1, was discovered on January 3, 2013, from Australia's Siding Spring Observatory. At the time, it was farther from the Sun than Jupiter is. Subsequent observations enabled scientists to calculate the trajectory the comet will follow as it swings past Mars. Observations in 2014 will continue to refine knowledge of the comet's path, but in approximate terms, Siding Spring's nucleus will come about as close to Mars as one-third of the distance between Earth and the Moon.

Observations of Comet Siding Spring are planned using resources on Earth, orbiting Earth, on Mars, and orbiting Mars, and some are already underway. NASA's Hubble Space Telescope and the NEOWISE

mission observed the comet in January both to characterize this first-time visitor from the Oort cloud and to study dust particle sizes and amounts produced by the comet for understanding potential risks to the Mars orbiters. Infrared imaging by NEOWISE reveals a comet that is active and dusty, even though still nearly three-fourths as far from the Sun as Jupiter is. Groundbased observatories such as the NASA Infrared Telescope Facility are also expected to join in as the comet becomes favorably positioned for viewing.

As the comet nears Mars, NASA assets there will be used to study this visitor from distant reaches of the solar system. “We could learn about the nucleus — its shape, its rotation, whether some areas on its surface are darker than others,” Zurek said.

Researchers using spacecraft at Mars gained experience at trying to observe a different comet in 2013, as Comet ISON (formally C/2012 S1) approached Mars. That comet’s Mars-flyby distance was about 80 times farther than Siding Spring’s will be. Another difference is that ISON continued inward past Mars for nearly two months, briefly becoming visible to some unaided-eye skywatchers on Earth before flying very close to the Sun and disintegrating. Siding Spring will reach its closest approach to the Sun just six days after its Mars flyby. It won’t put on a show for Earth, and it won’t return to the inner solar system for about a million years.

At Comet Siding Spring’s flyby distance, the High Resolution Imaging Science Experiment (HiRISE) camera on NASA’s Mars Reconnaissance Orbiter could provide imagery with resolution of dozens of pixels across the diameter of the nucleus. When HiRISE observed Comet ISON, the nucleus was less than one pixel across. ISON did not get bright enough to make itself visible to other cameras at Mars that made attempted observations, but Siding Spring could provide a better observation opportunity.

Cameras on the Mars rovers Curiosity and Opportunity might watch for meteors in the sky that would be an indication of the abundance of particles in the comet’s tail, although the geometry of the flyby would put most of the meteors in daytime sky instead of dark sky. “A third aspect for investigation could be what effect the infalling particles have on the upper atmosphere of Mars,” Zurek said. “They might heat it and expand it, not unlike the effect of a global dust storm.” Infrared-sensing instruments on Mars Reconnaissance Orbiter and Odyssey might be used to watch for that effect.

One trait Siding Spring shares with ISON is unpredictability about how much it will brighten in the months before passing Mars. The degree to which Siding Spring brightens this spring will be an indicator of how much hazard it will present to spacecraft at Mars. “It’s way too early for us to know how much of a threat Siding Spring will be to our orbiters,” said JPL’s Soren Madsen, Mars Exploration Program chief engineer. “It could go either way. It could be a huge deal or it could be nothing — or anything in between.”

The path the nucleus will take is now known fairly well. The important unknowns are how much dust will come off the nucleus, when it will come off, and the geometry of the resulting coma and tail of the comet. During April and May, the comet will cross the range of distances from the Sun at which water ice on a comet’s surface typically becomes active — vaporizing and letting dust particles loose. Dust ejected then could get far enough from the nucleus by October to swarm around Mars.

"How active will Siding Spring be in April and May? We'll be watching that," Madsen said. "But if the red alarm starts sounding in May, it would be too late to start planning how to respond. That's why we're doing what we're doing right now." Two key strategies to lessen risk are to get orbiters behind Mars during the minutes of highest risk and to orient orbiters so that the most vulnerable parts are not in the line of fire.

The martian atmosphere, thin as it is, is dense enough to prevent dust from the comet from becoming a hazard to NASA's two Mars rovers active on the surface. Three orbiters are currently active at Mars: NASA's Mars Reconnaissance Orbiter (MRO) and Mars Odyssey, and the European Space Agency's Mars Express. Two more departed Earth in late 2013 and are due to enter orbit around Mars about three weeks before the Comet Siding Spring flyby: NASA's Mars Atmosphere and Volatile Evolution (MAVEN) and India's Mars Orbiter Mission.

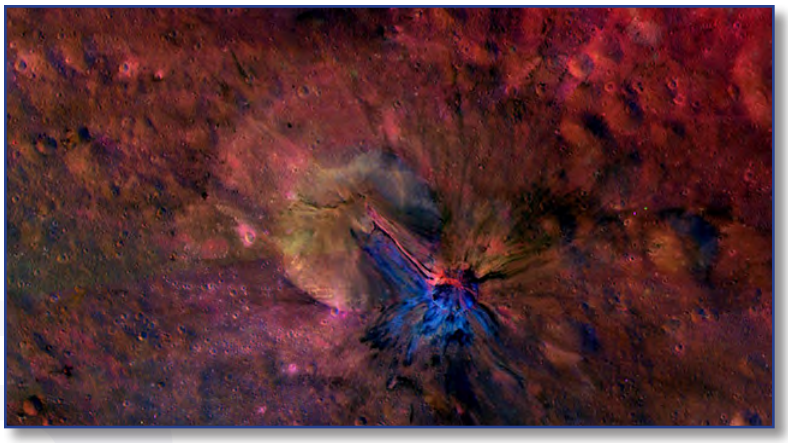
Orbiters are designed with the risk of space-dust collisions in mind. Most such collisions do not damage a mission. Design factors such as blanketing and protected placement of vulnerable components help. Over a five-year span for a Mars orbiter, NASA figures on a few percent chance of significant damage to a spacecraft from the background level of impacts from such particles, called meteoroids. Whether the Siding Spring level will pack that much hazard — or perhaps greater than 10 times more — into a few hours will depend on how active it becomes. This comet is orbiting the Sun in almost the opposite direction as Mars and the other planets. The nucleus and the dust particles it sheds will be traveling at about 35 miles (56 kilometers) per second, relative to the Mars orbiters. That's about 50 times faster than a bullet from a high-powered rifle and double or triple the velocity of background meteoroid impacts.

If managers choose to position orbiters behind Mars during the peak risk, the further in advance any orbit-adjustment maneuvers can be made, the less fuel will be consumed. Advance work is also crucial for the other main option: reorienting a spacecraft to keep its least-vulnerable side facing the oncoming stream of comet particles. The safest orientation in terms of comet dust may be a poor one for maintaining power or communications. "These changes would require a huge amount of testing," Madsen said. "There's a lot of preparation we need to do now, to prepare ourselves in case we learn in May that the flyby will be hazardous."

For more information, visit *mars.nasa.gov/comets/sidingspring*.

Dawn Creates Guide to Vesta's Hidden Attractions

Some beauty is revealed only at a second glance. When viewed with the human eye, the giant asteroid Vesta, which was the object of scrutiny by the Dawn spacecraft from 2011 to 2012, is quite unspectacular color-wise. Vesta looks grayish, pitted by a variety of large and small craters. But scientists at the Max Planck Institute for Solar System Research in Katlenburg-Lindau, Germany, have reanalyzed the images of this giant asteroid obtained by Dawn's framing camera. They assigned colors to different wavelengths of light and, in the process, revealed in unprecedented detail not only geological structures that are invisible to the naked eye, but also landscapes of incomparable beauty. Researchers at Max Planck can now see structures such as melts from impacts, craters buried by quakes, and foreign material brought by space rocks, visible with a resolution of 200 feet (60 meters) per pixel.



This colorful composite image from NASA's Dawn mission shows the flow of material inside and outside a crater called Aelia on the giant asteroid Vesta. The area is around 14°S latitude. The images that went into this composite were obtained by Dawn's framing camera from September to October 2011. Credit: NASA/JPL-Caltech/UCLAMPS/DLR/IDA.

"The key to these images is the seven color filters of the camera system onboard the spacecraft," said Andreas Nathues, the framing camera team lead at Max Planck. Since different minerals reflect light of different wavelengths to different degrees, the filters help reveal compositional differences that remain hidden without them. In addition, scientists calibrated the data so that the finest variations in brightness can be seen. In the new colorized images, different colors indicate different materials on the surface of Vesta. They reveal impressive formations and a wide range of geological diversity, said Nathues. But above all, the color-coded images are impressive because of their beauty.

"No artist could paint something like that. Only nature can do this," said Martin Hoffman, a member of the framing camera team also at Max Planck. Pictures of the crater Aelia, the crater Antonia, and an area near the crater Sextilia show some of Vesta's most impressive sites.

Dawn visited Vesta from July 2011 to September 2012. The spacecraft is currently on its way to its second destination, the dwarf planet Ceres. Ceres is the largest object in the main asteroid belt between Mars and Jupiter. For more information, visit *www.nasa.gov/dawn* and *dawn.jpl.nasa.gov*.

Herschel Telescope Detects Water on Dwarf Planet Ceres

Scientists using the Herschel space observatory have made the first definitive detection of water vapor on the largest and roundest object in the asteroid belt, Ceres. Plumes of water vapor are thought to shoot up periodically from Ceres when portions of its icy surface warm slightly. Ceres is classified as a dwarf planet, a solar system body bigger than an asteroid and smaller than a planet. Herschel is a European Space Agency (ESA) mission with important NASA contributions.

"This is the first time water vapor has been unequivocally detected on Ceres or any other object in the asteroid belt and provides proof that Ceres has an icy surface and an atmosphere," said Michael Küppers of ESA in Spain, lead author of a paper in the journal *Nature*.

The results come at the right time for NASA's Dawn mission, which is on its way to Ceres now after spending more than a year orbiting the large asteroid Vesta. Dawn is scheduled to arrive at Ceres in the spring of 2015, where it will take the closest look ever at its surface. "We've got a spacecraft on the way to Ceres, so we don't have to wait long before getting more context on this intriguing result, right from the source itself," said Carol Raymond, the deputy principal investigator for Dawn at NASA's Jet

Propulsion Laboratory. “Dawn will map the geology and chemistry of the surface in high resolution, revealing the processes that drive the outgassing activity.”

Dwarf planet Ceres is located in the main asteroid belt, between the orbits of Mars and Jupiter, as illustrated in this artist’s conception. Observations by the Herschel space observatory between 2011 and 2013 found that the dwarf planet has a thin water vapor atmosphere. This is the first unambiguous detection of water vapor around an object in the asteroid belt. Credit: ESA/ATG Medialab.

For the last century, Ceres was known as the largest asteroid in our solar system. But in 2006, the International Astronomical Union, the governing organization responsible for naming planetary objects, reclassified Ceres as a dwarf planet because of its large size. It is roughly 590 miles (950 kilometers) in diameter. When it first was spotted in 1801, astronomers thought it was a planet orbiting between Mars and Jupiter. Later, other cosmic bodies with similar orbits were found, marking the discovery of our solar system’s main belt of asteroids. Scientists believe Ceres contains rock in its interior with a thick mantle of ice that, if melted, would amount to more fresh water than is present on all of Earth. The materials making up Ceres likely date from the first few million years of our solar system’s existence and accumulated before the planets formed.

Until now, ice had been theorized to exist on Ceres but had not been detected conclusively. It took Herschel’s far-infrared vision to finally see a clear spectral signature of the water vapor. But Herschel did not see water vapor every time it looked. While the telescope spied water vapor four different times, on one occasion there was no signature. Here is what scientists think is happening: When Ceres swings through the part of its orbit that is closer to the Sun, a portion of its icy surface becomes warm enough to cause water vapor to escape in plumes at a rate of about 6 kilograms (13 pounds) per second. When Ceres is in the colder part of its orbit, no water escapes.

The strength of the signal also varied over hours, weeks, and months, because of the water vapor plumes rotating in and out of Herschel’s views as the object spun on its axis. This enabled the scientists to localize the source of water to two darker spots on the surface of Ceres, previously seen by NASA’s Hubble Space Telescope and groundbased telescopes. The dark spots might be more likely to outgas because dark material warms faster than light material. When the Dawn spacecraft arrives at Ceres, it will be able to investigate these features.

The results are somewhat unexpected because comets, the icier cousins of asteroids, are known typically to sprout jets and plumes, while objects in the asteroid belt are not. “The lines are becoming more and more blurred between comets and asteroids,” said Seungwon Lee of JPL, who helped with the water vapor models along with Paul von Allmen, also of JPL. “We knew before about main belt asteroids that show comet-like activity, but this is the first detection of water vapor in an asteroid-like object.”

The research is part of the Measurements of 11 Asteroids and Comets Using Herschel (MACH-11) program, which used Herschel to look at small bodies that have been or will be visited by spacecraft, including the targets of NASA's previous Deep Impact mission and upcoming Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-Rex). Laurence O' Rourke of the European Space Agency is the principal investigator of the MACH-11 program.

While Herschel stopped making observations in April 2013 after running out of liquid coolant, as expected, scientists continue to analyze its data. More information about Herschel is available at *www.esa.int/SPECIALS/herschel* and *www.nasa.gov/herschel*.

Hubble Discovers Water Vapor Venting from Jupiter's Moon Europa

The NASA/ESA Hubble Space Telescope has discovered water vapor erupting from the frigid surface of Jupiter's moon Europa, in one or more localized plumes near its south pole. Europa is already thought to harbor a liquid ocean beneath its icy crust, making the moon one of the main targets in the search for habitable worlds away from Earth. This new finding is the first observational evidence of water vapor being ejected off the moon's surface.

This artist's impression shows Jupiter and its moon Europa using actual Jupiter and Europa images in visible light. The Hubble ultraviolet images showing the faint emission from the water vapor plumes have been superimposed, respecting the size but not the brightness of the plumes. Credit: NASA, ESA, and M. Kornmesser.

"The discovery that water vapor is ejected near the south pole strengthens Europa's position as the top candidate for potential habitability," said lead author Lorenz Roth of the Southwest Research Institute in San Antonio, Texas. "However, we do not know yet if these plumes are connected to subsurface liquid water or not." The Hubble findings were published in the December 12 online issue of *Science Express*, and reported at the December meeting of the American Geophysical Union in San Francisco, California.

The Hubble discovery makes Europa only the second moon in the solar system known to have water vapor plumes. In 2005, plumes of water vapor and dust were detected by NASA's Cassini orbiter spewing off the surface of the saturnian moon Enceladus. The Europa plumes were discovered by Hubble observations in December 2012. The Space Telescope Imaging Spectrograph (STIS) detected faint ultraviolet light from an aurora at the moon's south pole. This aurora is driven by Jupiter's intense magnetic field, which causes particles to reach such high speeds that they can split the water molecules in the plume when they hit them, resulting in oxygen and hydrogen ions that leave their telltale imprint in the colors of the aurora. So far, only water vapor has been detected — unlike the plumes on Enceladus, which also contain ice and dust particles.

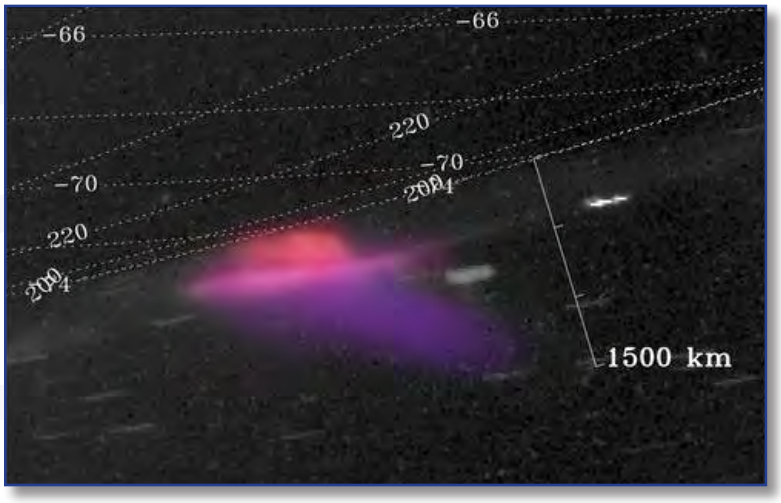
"We pushed Hubble to its limits to see this very faint emission," said co-lead author and principal investigator of the Hubble observing campaign Joachim Saur of the University of Cologne, Germany.

"Only after a particular camera on the Hubble Space Telescope had been repaired on the last servicing mission by the space shuttle did we gain the sensitivity to really search for these plumes."

Roth suggests long cracks on Europa's surface, known as linea, might be venting water vapor into space. Similar fissures have been photographed near Enceladus' south pole by the Cassini spacecraft. It is unknown how deep inside Europa's crust the source of the water may be. Roth asks, "Do the vents extend down to a subsurface ocean or are the ejecta simply from warmed ice caused by friction stresses near the surface?"

Also like Enceladus, the Hubble team found that the intensity of the plumes varies with Europa's orbital position. Active geysers have only been seen when the moon is furthest from Jupiter. But the researchers could not detect any sign of venting when Europa is closer to Jupiter. One explanation is that the long fractures in the ice crust experience more stress as gravitational tidal forces push and pull on the moon and so open vents at larger distances from Jupiter. The vents are narrowed or closed when at closest approach to the gas giant planet. (When Europa orbits around Jupiter, the moon experiences varying tidal forces at different points in its orbit. The tidal stresses compress the vents at the south pole region when Europa is closest to Jupiter, and stretch them when Europa is furthest away, making it possible for the vents to open up. A subsurface ocean wold allow the stresses on Europa's surface to be much stronger as the interior would be malleable and flexible.) Team member Kurt Retherford, also of the Southwest Research Institute, points out that "the plume variability supports a key prediction that we should see this kind of tidal effect if there is a subsurface ocean on Europa."

Future space probe missions to Europa could confirm that the exact locations and sizes of vents and determine whether they connect to liquid subsurface reservoirs. It is important news for missions such as ESA's JUpiter ICy moons Explorer (JUICE), a mission planned for launch in 2022, which aims to explore both Jupiter and three of its largest moons: Ganymede, Callisto, and Europa.



While the curtain-like auroras we see at Earth are green at the bottom and red at the top, NASA's Cassini spacecraft has shown us similar curtain-like auroras at Saturn that are red at the bottom and purple at the top. This is how the auroras would look to the human eye. Credit: NASA/JPL-Caltech/Space Science Institute.

NASA Spacecraft Get a 360° View of Saturn's Auroras

NASA trained several pairs of eyes on Saturn as the planet put on a dancing light show at its poles. While NASA's Hubble Space Telescope, orbiting around Earth, was able to observe the northern auroras in ultraviolet wavelengths, NASA's Cassini spacecraft, orbiting around Saturn, got complementary close-up views in infrared, visible-light, and ultraviolet wavelengths. Cassini could also see northern and southern parts of Saturn that don't

face Earth. The result is a kind of step-by-step choreography detailing how the auroras move, showing the complexity of these auroras and how scientists can connect an outburst from the Sun and its effect on the magnetic environment at Saturn. A new video showing aurora images from Hubble and Cassini is available at *saturn.jpl.nasa.gov/video/videodetails/?videoID=272*. "Saturn's auroras can be fickle — you may see fireworks, you may see nothing," said Jonathan Nichols of the University of Leicester in England, who led the work on the Hubble images. "In 2013, we were treated to a veritable smorgasbord of dancing auroras, from steadily shining rings to super-fast bursts of light shooting across the pole."

The Hubble and Cassini images were focused on April and May of 2013. Images from Cassini's ultraviolet imaging spectrometer (UVIS), obtained from an unusually close range of about six Saturn radii, provided a look at the changing patterns of faint emissions on scales of a few hundred miles (kilometers) and tied the changes in the auroras to the fluctuating wind of charged particles blowing off the sun and flowing past Saturn. "This is our best look yet at the rapidly changing patterns of auroral emission," said Wayne Pryor, a Cassini co-investigator at Central Arizona College in Coolidge, Arizona. "Some bright spots come and go from image to image. Other bright features persist and rotate around the pole, but at a rate slower than Saturn's rotation."

The UVIS images, which are also being analyzed by team associate Aikaterini Radioti at the University of Liege, Belgium, also suggest that one way the bright auroral storms may be produced is by the formation of new connections between magnetic field lines. That process causes storms in the magnetic bubble around Earth. The movie also shows one persistent bright patch of the aurora rotating in lockstep with the orbital position of Saturn's moon Mimas. While previous UVIS images had shown an intermittent auroral bright spot magnetically linked to the moon Enceladus, the new movie suggests another Saturn moon can influence the light show as well.

The new data also give scientists clues to a long-standing mystery about the atmospheres of giant outer planets. "Scientists have wondered why the high atmospheres of Saturn and other gas giants are heated far beyond what might normally be expected by their distance from the Sun," said Sarah Badman, a Cassini visual and infrared mapping spectrometer team associate at Lancaster University, England. "By looking at these long sequences of images taken by different instruments, we can discover where the aurora heats the atmosphere as the particles dive into it and how long the cooking occurs."

The visible-light data have helped scientists figure out the colors of Saturn's auroras. While the curtain-like auroras we see at Earth are green at the bottom and red at the top, Cassini's imaging cameras have shown us similar curtain-like auroras at Saturn that are red at the bottom and purple at the top, said Ulyana Dyudina, an imaging team associate at the California Institute of Technology, Pasadena, California.

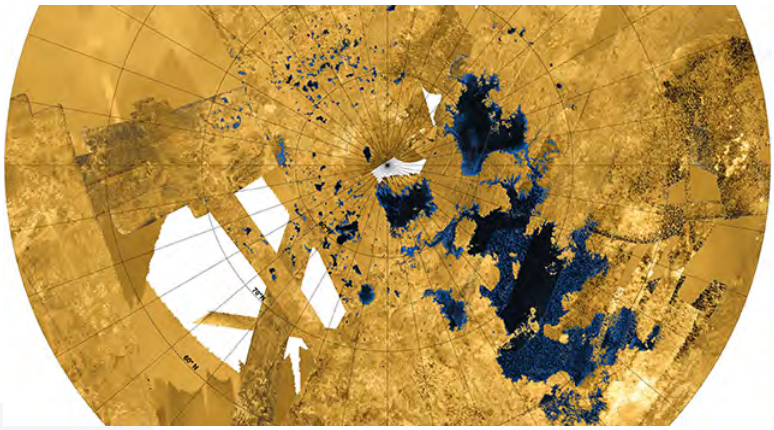
The color difference occurs because Earth's auroras are dominated by excited nitrogen and oxygen molecules, and Saturn's auroras are dominated by excited hydrogen molecules. "While we expected to see some red in Saturn's aurora because hydrogen emits some red light when it gets excited, we also knew there could be color variations depending on the energies of the charged particles bombarding the atmosphere and the density of the atmosphere," Dyudina said. "We were thrilled to learn about this colorful display that no one had seen before."

Scientists hope additional Cassini work will illuminate how clouds of charged particles move around the planet as it spins and receives blasts of solar material from the Sun. “The auroras at Saturn are some of the planet’s most glamorous features — and there was no escaping NASA’s paparazzi-like attention,” said Marcia Burton, a Cassini fields and particles scientist at NASA’s Jet Propulsion Laboratory, who is helping to coordinate these observations. “As we move into the part of the 11-year solar cycle where the Sun is sending out more blobs of plasma, we hope to sort out the differences between the effects of solar activity and the internal dynamics of the Saturn system.”

There is still more work to do. A group of scientists led by Tom Stallard at the University of Leicester is busy analyzing complementary data taken during the same time window by two groundbased telescopes in Hawaii — the W. M. Keck Observatory and NASA’s Infrared Telescope Facility. The results will help them understand how particles are ionized in Saturn’s upper atmosphere and will help them put a decade of groundbased telescope observations of Saturn in perspective, because they can see what disturbance in the data comes from Earth’s atmosphere.

For more information, visit *www.nasa.gov/cassini* and *saturn.jpl.nasa.gov.*

NASA’s Cassini Spacecraft Reveals Clues About Titan’s Seas



This colorized mosaic from NASA’s Cassini mission shows the most complete view yet of Titan’s northern land of lakes and seas. Saturn’s moon Titan is the only world in our solar system other than Earth that has stable liquid on its surface. The liquid in Titan’s lakes and seas is mostly methane and ethane. Credit: NASA/JPL-Caltech/ASI/USGS.

NASA’s Cassini spacecraft is providing scientists with key clues about Saturn’s moon Titan, and in particular, its hydrocarbon lakes and seas. Titan is one of the most Earth-like places in the solar system, and the only place other than our planet that has stable liquid on its surface.

Cassini’s recent close flybys are bringing into sharper focus a region in Titan’s northern hemisphere that sparkles with almost all of the moon’s seas and lakes. Scientists working with the spacecraft’s radar instrument have put together the most detailed multi-image mosaic of that region to date. The image includes all the seas and most of the major lakes. Some of the flybys tracked over areas that previously were seen at a different angle, so researchers have been able to create a flyover of the area around Titan’s largest and second largest seas, known as Kraken Mare and Ligeia Mare, respectively, and some of the nearby lakes.

“Learning about surface features like lakes and seas helps us to understand how Titan’s liquids, solids, and gases interact to make it so Earth-like,” said Steve Wall, acting radar team lead at NASA’s Jet Propulsion Laboratory. “While these two worlds aren’t exactly the same, it shows us more and more Earth-like processes as we get new views.”

These new images show Kraken Mare is more extensive and complex than previously thought. They also show nearly all the lakes on Titan fall into an area covering about 600 miles by 1100 miles (900 kilometers by 1800 kilometers). Only 3% of the liquid at Titan falls outside this area.

"Scientists have been wondering why Titan's lakes are where they are. These images show us that the bedrock and geology must be creating a particularly inviting environment for lakes in this box," said Randolph Kirk, a Cassini radar team member at the U.S. Geological Survey in Flagstaff, Arizona. "We think it may be something like the formation of the prehistoric lake called Lake Lahontan near Lake Tahoe in Nevada and California, where deformation of the crust created fissures that could be filled up with liquid."

A creative application of a method previously used to analyze data at Mars also revealed that Ligeia Mare is about 560 feet (170 meters) deep. This is the first time scientists have been able to plumb the bottom of a lake or sea on Titan. This was possible partly because the liquid turned out to be very pure, allowing the radar signal to pass through it easily. The liquid surface may be as smooth as the paint on our cars, and it is very clear to radar eyes. The new results indicate the liquid is mostly methane, somewhat similar to a liquid form of natural gas on Earth.

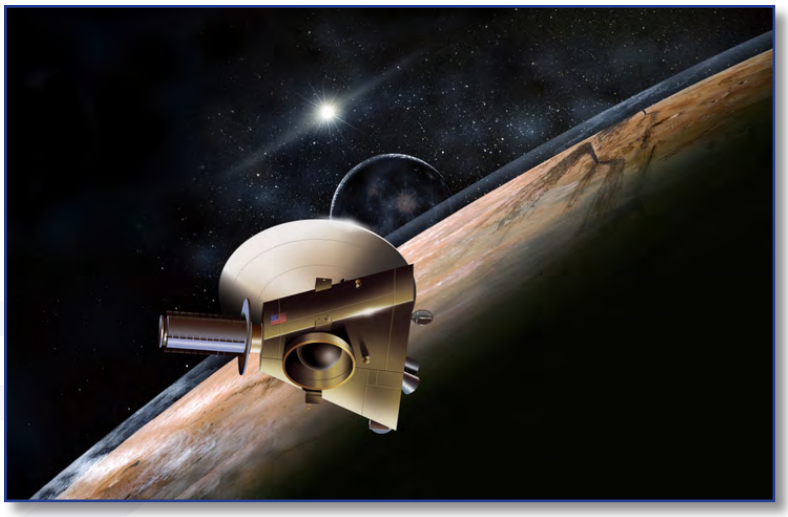
"Ligeia Mare turned out to be just the right depth for radar to detect a signal back from the sea floor, which is a signal we didn't think we'd be able to get," said Marco Mastrogiuseppe, a Cassini radar team associate at Sapienza University of Rome. "The measurement we made shows Ligeia to be deeper in at least one place than the average depth of Lake Michigan."

One implication is that Cassini scientists now can estimate the total volume of the liquids on Titan. Based on Mastrogiuseppe's work, calculations made by Alexander Hayes of Cornell University in Ithaca, New York, show there are about 2000 cubic miles (9000 cubic kilometers) of liquid hydrocarbon, about 40 times more than in all the proven oil reservoirs on Earth. As Cassini gets closer to northern summer in the Saturn system, mission scientists look forward to potentially the most exciting time for weather at Titan's northern hemisphere.

Countdown to Pluto

Are we there yet? One of the fastest spacecraft ever built — NASA's New Horizons — is hurtling through the void at nearly one million miles per day. Launched in 2006, it has been in flight longer than some missions last, and it is nearing its destination: Pluto. "The encounter begins next January," says Alan Stern, of the Southwest Research Institute and the mission's principal investigator. "We're less than a year away."

Closest approach is scheduled for July 2015 when New Horizons flies only 10,000 kilometers from Pluto, but the spacecraft will be busy long before that date. The first step, in January 2015, is an intensive campaign of photography by the Long Range Reconnaissance Imager (LORRI). This will help mission controllers pinpoint Pluto's location, which is uncertain by a few thousand kilometers. "LORRI will photograph the planet against known background star fields," explains Stern. "We'll use the images to refine Pluto's distance from the spacecraft, and then fire the engines to make any necessary corrections."



Artist's concept of the New Horizons spacecraft during a planned encounter with Pluto and its moon, Charon. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).

At first, Pluto and its large moon Charon will be little more than distant pinpricks — "a couple of fat pixels," says Stern — but soon they will swell into full-fledged worlds. By late April 2015, the approaching spacecraft will be taking pictures of Pluto that surpass the best images from Hubble. By closest approach in July 2015, a whole new world will open up to the spacecraft's cameras. If New Horizons flew over Earth at the same altitude, it could see individual buildings and their shapes. For more information, visit *pluto.jhuapl.edu*.

Rosetta, the Comet-Chasing Spacecraft, is Awake

The European Space Agency's (ESA) Rosetta spacecraft recently "woke up" after a record 957 days of hibernation. The first communication from the spacecraft arrived at the European Space Operations Center in Darmstadt, Germany, at 7:18 p.m. local time on January 21. The signal was received by ground stations at the Goldstone, California, and Canberra, Australia, complexes of NASA's Deep Space Network. Rosetta, heading toward Comet 67P/Churyumov-Gerasimenko, is an international mission spearheaded by ESA with support and instruments provided by NASA.

Comets are among the most beautiful and least understood nomads of the night sky. To date, half a dozen of these most heavenly of heavenly bodies have been visited by spacecraft in an attempt to unlock their secrets. All these missions have had one thing in common: the high-speed flyby. Like two ships passing in the night (or one ship and one icy dirtball), they screamed past each other at hypervelocity — providing valuable insight, but fleeting glimpses, into the life of a comet. That is, until Rosetta.

An artist's view of Rosetta, the European Space Agency's cometary probe with NASA contributions. The spacecraft is covered with dark thermal insulation in order to retain its warmth while venturing into the coldness of the outer solar system, beyond Mars orbit. Credit: ESA.

The goal of the Rosetta mission is to observe one such space-bound icy dirt ball from up close — for

months on end. The spacecraft, festooned with 25 instruments between its lander and orbiter (including three from NASA), will monitor Comet 67P/Churyumov-Gerasimenko as it makes its nosedive into, and then climbs out of, the inner solar system. Over a period of 16 months of observations, the comet is expected to transform from a small, frozen world into a roiling mass of ice and dust, complete with surface eruptions; mini-earthquakes; basketball-sized, fluffy ice particles; and spewing jets of carbon dioxide and cyanide. "We are going to be in the cometary catbird seat on this one," said Claudia Alexander, project scientist for U.S. Rosetta from NASA's Jet Propulsion Laboratory. "To have an extended presence in the neighborhood of a comet as it goes through so many changes should change our perspective on what it is to be a comet."

Since work began on Rosetta back in 1993, scientists and engineers from all over Europe and the U.S. have been combining their talents to build an orbiter and a lander for this unique expedition. NASA's contribution includes three of the orbiter's instruments (an ultraviolet spectrometer called Alice; the Microwave Instrument for Rosetta Orbiter; and the Ion and Electron Sensor), as well as part of the electronics package for an instrument called the Double Focusing Mass Spectrometer, which is part of the Swiss-built Rosetta Orbiter Spectrometer for Ion and Neutral Analysis instrument. NASA is also providing U.S. science investigators for selected non-U.S. instruments and is involved to a greater or lesser degree in 7 of the mission's 25 instruments. NASA's Deep Space Network provides support for ESA's Ground Station Network for spacecraft tracking and navigation. "All the instruments onboard Rosetta and the Philae lander are designed to work synergistically," said Sam Gulkis of JPL, the principal investigator for the Microwave Instrument for Rosetta Orbiter. "They will all work together to create the most complete picture of a comet to date, telling us how the comet works, what it is made of, and what it can tell us about the origins of the solar system."

The three NASA-supplied instruments are part of the orbiter's scientific payload. Rosetta's Microwave Instrument for Rosetta Orbiter specializes in the thermal properties. The instrument combines a spectrometer and radiometer, so it can sense temperature and identify chemicals located on or near the comet's surface, and even in the dust and ices jetting out from it. The instrument will also see the gaseous activity through the dusty cloud of material. Rosetta scientists will use it to determine how different materials in the comet change from ice to gas, and to observe how much it changes in temperature as it approaches the Sun.

Like the Microwave for Rosetta Orbiter, the Alice instrument contains a spectrometer. But Alice looks at the ultraviolet portion of the spectrum. Alice will analyze gases in the coma and tail and measure the comet's production rates of water and carbon monoxide and dioxide. It will provide information on the surface composition of the nucleus, and make a potentially key measurement of argon, which will be a big clue about what the temperature was in the primordial solar system when the comet's nucleus originally formed (more than 4.6 billion years ago).

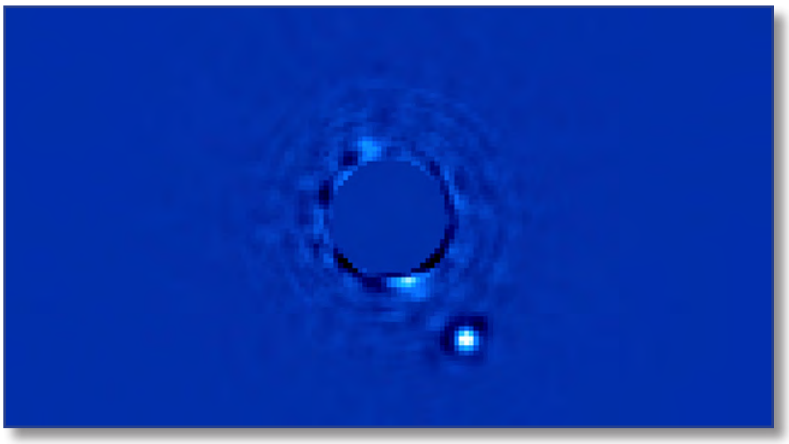
The Rosetta orbiter's Ion and Electron Sensor is part of a suite of five instruments to characterize the plasma environment of the comet — in particular, its coma, which develops when the comet approaches the Sun. The Sun's outer atmosphere, the solar wind, interacts with the gas flowing out from the comet, and the instrument will measure the charged particles it comes in contact with as the orbiter approaches the comet's nucleus.

All three instruments are slated to begin science collection by early summer. Along with the pure science they will provide, their data are expected to help Rosetta project management determine where to attempt to land their Philae lander on the comet in November. “It feels good to be part of a team that is on the cusp of making some space exploration history,” said Art Chmielewski, NASA’s project manager for U.S. Rosetta, based at JPL. “There are so many exciting elements and big milestones coming up in this mission that it feels like I should buy a ticket and a big box of popcorn. Rosetta is going to be a remarkable ride.”

More information about Rosetta is available at *www.esa.int/rosetta* and *rosetta.jpl.nasa.gov*.

Powerful Planet Finder Turns Its Eye to the Sky

After nearly a decade of development, construction, and testing, the world’s most advanced instrument for directly imaging and analyzing planets around other stars is pointing skyward and collecting light from distant worlds. The instrument, called the Gemini Planet Imager (GPI), was designed, built, and optimized for imaging giant planets next to bright stars, in addition to studying dusty disks around young stars. It is the most advanced instrument of its kind to be deployed on one of the world’s biggest telescopes — the 26-foot (8-meter) Gemini South telescope in Chile.



This image taken by the Gemini Planet Imager (GPI) shows a planet orbiting the star Beta Pictoris. In addition to the image, the GPI obtains spectral information from every pixel element in the field of view, allowing scientists to study the planet in great detail. Credit: Gemini/ Christian Marois, NRC Canada.

Imaging a planet next to a star is a tricky task. The planet is much fainter than its star, and also appears very close. These challenges make the act of separating the planet’s light from the glare of the star difficult. NASA’s Jet Propulsion Laboratory contributed to the project by designing and building an ultraprecise infrared sensor to measure small distortions in starlight that might mask a planet. “Our tasks were two-fold,” said Kent Wallace, JPL’s subsystem technical lead for the project. “First, keep the star centered on the instrument so that its glare is blocked as much as possible. Second, ensure the instrument itself is stable during the very long exposures required to image faint companions.”

GPI detects infrared, or heat, radiation from young Jupiter-like planets in wide orbits around other stars. Those are equivalent to the giant planets in our own solar system not long after their formation. Every planet GPI sees can be studied in detail, revealing components of their atmospheres. Although GPI was designed to look at distant planets, it can also observe objects in our solar system. Test images of Jupiter’s moon Europa, for example, can allow scientists to map changes in the satellite’s surface composition. More information is available at *www.gemini.edu*.

NASA's Deep Space Network: The Original "Wireless Network" Turns 50

Beam Wave Guide antennas at Goldstone, known as the "Beam Waveguide Cluster." Each antenna is 111.5 feet (34 meters) in diameter. They're located in an area at Goldstone called "Apollo Valley." Credit: NASA/JPL-Caltech.

NASA's Deep Space Network (DSN), the world's largest and most powerful communications system for "talking to" spacecraft, reached a milestone on December 24: the 50th anniversary of its official creation. Over the past 50 years, antennas of the DSN have communicated with just about every mission that has gone to the Moon or beyond. The historic communiqués include "That's one small step for (a) man. One giant leap for mankind"; numerous encounters with the outer planets of our solar system; images taken by rovers exploring Mars; and the data confirming that NASA's Voyager spacecraft had finally entered interstellar space. The Deep Space Network has been so critical to so many missions over the decades, the network's team members like to use the phrase "Don't leave Earth without us."

From the very beginning of NASA's space program, it was clear that a simple, direct way to communicate with missions in deep space would be needed. For example, what is the purpose of sending a spacecraft to Mars if we can't receive data, images, and other vital information from that spacecraft? What is now known as the Deep Space Network first existed as just a few small antennas called the Deep Space Instrumentation Facility. The facility was originally operated by the U.S. Army in the 1950s and then later moved over to the jurisdiction of the newly created National Aeronautics and Space Administration (NASA). On December 24, 1963, the Deep Space Instrumentation Facility officially morphed into the DSN and quickly became the de facto network for any planned missions into deep space. Three antenna complexes were established around the globe, spread out at roughly 120° longitude so that even as Earth rotated, spacecraft would always be above the horizon of at least one complex. While some of the communication facilities have moved over the decades, today the three complexes, which operate 24/7/365, are located in Canberra, Australia; Madrid, Spain; and Goldstone, California.

Space agencies in Europe, Japan, and Russia have all relied on the DSN when planning and communicating with their own missions over the decades. The DSN has been used recently by India's first interplanetary probe, the Mars Orbiter Mission (MOM). "Today, the DSN supports a fleet of more than 30 U.S. and international robotic space missions," said DSN Project Manager Al Bhanji of NASA's Jet Propulsion Laboratory, which manages the Deep Space Network. "Without the DSN, we would never have been able to undertake voyages to Mercury and Venus [or] visit asteroids and comets; we'd never have seen the stunning images of robots on Mars, or close-up views of the majestic rings of Saturn."

In addition to allowing missions to upload and download data to and from dozens of spacecraft, the network helps navigators pinpoint spots for landings and conduct burns that place spacecraft into orbit around other planets, or fine-tune their trajectory. Currently, the list of spacecraft supported by the DSN includes NASA's Curiosity rover on Mars, the Spitzer Space Telescope, the Saturn explorer Cassini, and the two Voyager spacecraft, which are more than 9.6 billion miles (15.5 billion kilometers) away from Earth.

The DSN is also instrumental in carrying out its own science investigations. For instance, the 230-foot (70-meter) antenna at Goldstone is capable of using its radar to "ping" the near-Earth asteroids to determine a highly accurate position and velocity, and scientists are then able to calculate trajectories the asteroids will take over the next 100 years or more. This is crucial for tracking asteroids that could potentially cause damage were they to impact Earth. If an asteroid is close enough, they can also use the radar to "image" the object to determine its size, shape, and rotation. Additionally, by combining signals from the DSN antennas with other radio telescopes in an appropriate manner, one can create a "synthetic telescope" that's able to peer into the cores of active galaxies halfway across the observable universe. Likewise, the DSN can be used to probe interiors of planets in our own galaxy, study the solar wind, and study gravitational physics.

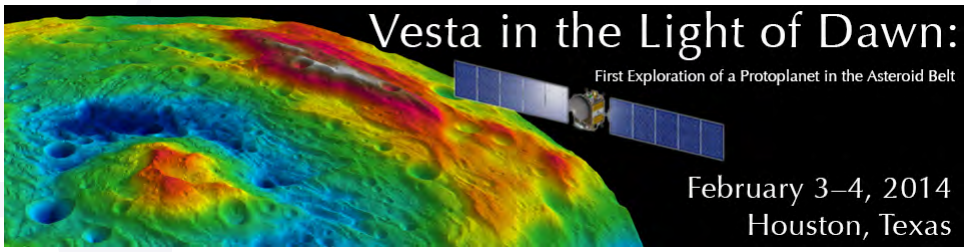
The future of the DSN looks bright, with optical communications on the horizon to augment the traditional RF-technology (radio waves moving at the speed of light). Optical communications, when operational, will provide a dramatic increase in data return from science missions; the potential bandwidth carried by an optical communications laser beam is far greater than with traditional radio frequencies. In fact, the DSN team envisions the day, not so far off, when, in addition to returning photos of robotic wheel tracks in the dusty surface of Mars, they will be streaming video to a wide-eyed public as the first humans leave their own footprints on its surface.

"In 2063, when we celebrate the Deep Space Network's 100th anniversary, we can imagine that we might be recalling the amazing days when our antennas streamed high-res video as the first humans stepped onto the surface of Mars," said Al Bhanji. "Or that day when we discovered a new living 'Earth' orbiting a distant star." Of course, no one knows if or when that day might come. But the DSN will likely play a paramount role in breaking the "Earth-shattering" news.

For more information, visit *www.jpl.nasa.gov/dsn50.*

Vesta in the Light of Dawn: First Exploration of a Protoplanet in the Asteroid Belt

February 3–4, 2014, Houston, Texas



On February 3–4, 2014, 48 scientists and researchers met at the Lunar and Planetary Institute in Houston, Texas, for the first extended gathering devoted specifically to scientific analysis of the large asteroid (or dwarf planetoid) Vesta. The Vesta in the Light of Dawn workshop was also the first such meeting after the extensive global mapping of this body by the Dawn spacecraft in 2011–2012.

Vesta was the fourth asteroid to be observed in the main asteroid belt and is the second most massive after Ceres. During the Apollo era, it was realized that Vesta had a basaltic surface and an associated family of small (10-kilometer) asteroids (vestoids), and was the likely parent body of the howardite, eucrite, and diogenite (HED) meteorites. Vesta soon became established as perhaps the sole basaltic protoplanet that survived the collisional processes in the asteroid belt.

Shortly after the establishment of the principal-investigator-led Discovery mission program, proposals were submitted to NASA to send an orbiter to Vesta to test the HED-Vesta paradigm and more fully understand the history of the solar system as revealed by Vesta's surface. In 2001, the Dawn mission was selected for flight to Vesta (and then to Ceres). After a successful launch in September 2007, Dawn reached Vesta in July 2011, and obtained orbital measurements of its gravity, topography, surface color, visible and infrared reflectance, and neutron and gamma-ray emissions through September 2012.

This workshop gathered together the community of scientists involved in the study of Vesta to examine how well the observations supported the existing paradigms and how those paradigms might need to be altered in light of the returned data. The expectations had been that a large impact basin at the south pole would have excavated down to an olivine mantle, and that Vesta was completely devoid of water. Despite having in fact been excavated twice, the southern impact basins did not reveal olivine. Only scattered small olivine deposits were seen, and then only in the north. Perhaps even more surprising is the fact that Vesta is not completely dry. Not only does the regolith contain hydrogen, but there is also evidence of the possible presence of transient water inputs on the floors of craters and gullies in the crater walls. The young ages of these pitted terrains suggests that some ice is locked up in Vesta's crust today. This workshop began the process of reshaping the Vesta paradigm and integrating the origin and evolution of the asteroid belt properly with the history of water in the solar system. For more information about the workshop, including the detailed program and abstracts, visit *www.hou.usra.edu/meetings/vesta2014*.

Workshop on the Habitability of Icy Worlds

February 5–7, 2014, Pasadena, California

The Workshop on the Habitability of Icy Worlds, held in February at the Westin Hotel in Pasadena, California, was a unique opportunity to focus on the astrobiological potential of icy worlds in the outer solar system with a diverse mix of motivated planetary scientists and engineers. The workshop included thematic sessions such as "Water and Exotic Solvents" and "Chemical Energy for Life on Icy Worlds." Sessions involved both talks and panel discussions and all occurred sequentially, so there were no scheduling conflicts and attendees could see all presentations. The entire workshop was also broadcast live on the web, and time was allotted for posted questions to involve the online community.

The purpose of the workshop was to bring together experts and young scientists for a common goal: to gain an understanding of what is known about icy worlds, and what areas of research still need further exploration in order to inform future spacecraft missions to the outer solar system.

Talks covered the largest and most active icy worlds — Europa, Ganymede, Enceladus, and Titan — as well as targets of current missions (Ceres), oft-forgotten moons (Triton), and Kuiper belt objects. Experimental investigations into solubilities in Titan-relevant solvents, clathrate hydrates, tribochemical reactions, and aqueous glasses were reported. Theoretical studies included convective processes and potential transport mechanisms in Europa's ocean, models of seafloor reductant flux and possible biomass dynamics on Europa, and formation and evolution of an internal ocean on Titan, among others.

Following animated discussions of the science and theory related to the study of icy worlds, the workshop turned to the subject of missions, including those in the near future (JUICE, Europa Clipper) as well as more pioneering designs (IceMole, EurEx).

Outcomes of the workshop included the importance of basic research funding to support mission science, in addition to the necessity of global coverage of Europa to inform models and future missions. Chambers are being built to simulate many icy world environments (Titan, Mars, Pluto, icy world interiors), and these will be advertised for collaborative future efforts. Comparative plume science in the context of the Europa Clipper mission was also a topic of substantial interest.

New areas of research were identified that would be important for upcoming missions to icy worlds:

- The potential for micrometer-scale particles (such as bacterial spores) introduced from a spacecraft to be deposited onto the surface of an icy moon and transported into environments where the organisms might survive

- Damage/penetration depth of energetic particles in ices
- Theoretical and experimental investigations of energy flux, biomass dynamics, and the timescale of metabolism/evolution relevant for Europa
- Mechanistic exploration of how simple prebiotic chemical reactions lead to life
- Further study of "weird life" that might exist in these environments
- Determination of the limits of detection for biology (or possibly intermediates)
- Buoyant clathrates and the transportation of guest molecules
- Study of the "porosphere" — the porous and permeable space between the surface and bedrock

Obviously there are still many unanswered questions, but this workshop helped to bring the scientific community into focus on the next key advancements necessary to enable future mission science. Many younger attendees also pointed out that the main outcome of this workshop in their eyes was the forging of new potential collaborations. Regardless of whether attendees were veterans or new to planetary science, we all realized through this workshop that we have a great deal to learn about icy worlds. The workshop program, abstracts, and presentations are available at *www.hou.usra.edu/meetings/icyworlds2014*.

Dawn Data Now Available Online

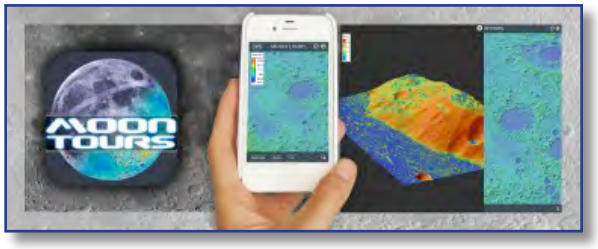
The Dawn project is pleased to announce that it has created a website where the public can freely access and download data and documentation.

Most of the data provided on this site are identical to the products provided by the Planetary Data System (PDS). However, the metadata provided has been augmented to include geometry information in both the Dawn Claudia and the Claudia Double Prime coordinate systems. All the Dawn publications cite the Dawn Claudia system, while the PDS site only provides metadata in the Claudia Double Prime system. This site is a work in progress. Many of the datasets that have been certified by the PDS but still have liens against the metadata are not yet available here. These data will be accessible from this site once the data are fully archived by the PDS.

To access the data, visit *dawndata.igpp.ucla.edu*.

Moon Tours

Moon Tours is a free app from NASA that makes it easy to conduct detailed explorations of the lunar surface using a mobile device. Moon Tours is the mobile version of NASA's Lunar Mapping and Modeling Portal (LMMP). LMMP (*www.lmmp.nasa.gov*) is the repository for over 600+ geospatial lunar data products and imagery from historical and current lunar missions for use by scientists, mission planners, students, and the public.



Moon Tours allows users to view all the publicly available lunar data from the LMMP and perform many of the functions available on the web browser version of the portal from their mobile devices. Available data products include scientifically referenced digital elevation maps (DEMs), slope maps, rock and hazard maps, gravity maps, mineralogy maps, and imagery ranging from the Apollo missions to the latest data from the Lunar Reconnaissance Orbiter (LRO). Whether you are a scientist, student, or just have an interest in our Moon, Moon Tours will show you lunar topography as you have never seen it before. With Moon Tours, you will be able to:

- View the map by panning and zooming using touch gestures
- Overlay any of the 600+ layers into the current view and adjust the transparency of any layer
- Determine the latitude and longitude of the current view as well as maintain context of the current view relative to the entire map
- Calculate the distance between two locations on the lunar surface
- Search for the names of features such as craters and hills

- Read an abstract about a particular data layer, or a longer document providing detailed information about the layer with citations and references to relevant scientific papers
- View lunar terrain data rendered in real-time 3D
- View a curated list of interesting sites on the lunar surface
- Generate interactive 3D models of regions on the Moon and save views for later analysis

Moon Tours is currently available for free download for iPhone and iPad from *https://itunes.apple.com/us/app/moon-tours/id696977262?mt=8*. An Android version is currently in development and will be available shortly.

The *Lunar and Planetary Information Bulletin* collects, synthesizes, and disseminates current research and findings in the planetary sciences to the research community, science libraries, educators, students, and the public. The *Bulletin* is dedicated to engaging, exciting, and educating those with a passion for the space sciences while developing future generations of explorers.

The *Bulletin* welcomes articles dealing with issues related to planetary science and exploration. Of special interest are articles describing web-based research and educational tools, meeting highlights and summaries, and descriptions of space missions. Peer-reviewed research articles, however, are not appropriate for publication in the *Bulletin*. Suggested topics can be e-mailed to the editors, who will provide guidelines for formatting and content.

Dr. Paul Schenk,
Scientific Editor (*schenk@lpi.usra.edu*)

Renée Dotson,
Production Editor (*rdotson@hou.usra.edu*)

Copy deadline for the next issue: May 15, 2014

To be added to the list to receive notification by e-mail of future issues, please send your e-mail address to *lpibed@lpi.usra.edu*, or visit *www.lpi.usra.edu/publications/newsletters/lpib/subscribe/index.cfm*.

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"Spotlight on Education" highlights events and programs that provide opportunities for planetary scientists to become involved in education and public outreach and to engage science educators and the community. If you know of space science educational programs or events that should be included, please contact the Lunar and Planetary Institute's Education Department at shupla@lpi.usra.edu.

Lunar and Planetary Science Conference: Education Opportunities

The 45th Lunar and Planetary Science Conference will be held March 17–21 at The Woodlands Waterway Marriott Hotel and Convention Center in The Woodlands, Texas. There are many E/PO events at LPSC available for people to get involved! Details about the events described below are available at *www.hou.usra.edu/meetings/lpsc2014*.

Education and Public Outreach Help Desk —
Scientists are invited to work one-on-one with E/PO professionals to (1) determine ways to get involved in E/PO that match their time and resources, and (2) achieve maximum impact with their E/PO efforts. Come join us to talk about E/PO!

- ***Tuesday, March 18, 1:30–5:00 p.m., Indian Springs Room***
- ***Wednesday, March 19, 12:00–1:15 p.m., Panther Creek Room***
- ***Thursday, March 20, 8:30–11:30 a.m., Panther Creek Room***

For more information, contact Sanlyn Buxner (*buxner@psi.edu*) and Jennifer Grier (*jgrier@psi.edu*).

E/PO Community Professional Development: Working with Diverse Audiences —
Sunday, March 16 (9:00 a.m.–5:00 p.m.), Indian Springs Room
This session for E/PO professionals and scientists who participate in education and public outreach activities will feature suggestions and lessons learned for addressing needs of diverse audiences, with a focus on rural and Hispanic/Latino audiences. NASA E/PO community and external experts will share their stories and suggestions from the field. Existing resources will be highlighted, including those on the Science Mission Directorate E/PO Community Workspace. For more information, contact Andrea Jones (*andrea.j.jones@nasa.gov*).

Planetary Science Undergraduate Faculty Workshop —
Sunday, March 16 (1:00–5:00 p.m.), Spring Room
Join us for this half-day workshop exploring a suite of teaching resources for the undergraduate classroom, including EarthSpace (an online repository for higher education materials in Earth and space science), strategies for using social media to connect and share with your community, and techniques

for assessment that will support and help you share the story of your education efforts. Register for the workshop at *www.surveymonkey.com/s/LPSC2014_undergrad_teaching_workshop* or contact Sanlyn Buxner (*buxner@psi.edu*).

E/PO Poster Sessions —
Tuesday, March 18 (6:00–9:00 p.m.), Town Center Exhibit Hall

- Scientist Engagement in E/PO — A Plethora of Possibilities
- Using Planetary Data and Resources for Student and Citizen Scientist Engagement
- Engaging the Public Through Diverse Venues and Media
- Evaluating Our Impact

YSS Undergraduate Research Conference —
Sunday, March 16 (8:30 a.m.–5:00 p.m.), Town Center Exhibit Hall

The Undergraduate Planetary Science Research Conference includes panels on "How to Choose the Grad School Right for You," "Alternative Careers in Science," and "Women in Planetary Science"; poster sessions where students will present their research to other students and to the scientific community; opportunities to meet other undergraduate researchers, graduate students, and scientists; and mentoring scientists to assist students. To assist as a meeting mentor, or to learn more details, contact Andy Shaner (*shaner@lpi.usra.edu*).

2014 NASA Planetary Science Summer School

NASA is currently accepting applications from science and engineering post-docs, recent Ph.D.s, and doctoral students for its 26th Annual Planetary Sciences Summer School at the NASA Jet Propulsion Laboratory in Pasadena, California. During the program and pre-session webinars, student teams will carry out the equivalent of an early mission concept study, prepare a proposal authorization review presentation, present it to a review board, and receive feedback. By the end of the session, student will have a clearer understanding of the life cycle of a space mission; relationships between mission design, cost, and schedule; and the tradeoffs necessary to stay within cost and schedule while preserving the quality of science. The 2014 sessions (June 16–20, July 14–18, and August 11–15) will address planetary exploration missions needing power system trade-offs, including the use of solar electric vs. Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs). The August session will have a targeted focus on spacecraft power systems. Application deadline is April 1. Partial financial support is available for a limited number of individuals. For more information and to apply, please visit *bit.ly/y8TPOl*.

Upcoming Eclipses!

A variety of lunar and solar eclipses will occur in 2014 and 2015; the E/PO community within the U.S. may want to take advantage of these opportunities to host events!

A total lunar eclipse will be visible early in the morning hours of April 15, 2014, for those living in the eastern continental U.S., and in the evening hours of April 14 for those on the west coast or in Hawaii and Alaska. Another total lunar eclipse will be visible October 8, 2014, visible for parts of North America and Australia.

While the annular solar eclipse on April 29, 2014, is best seen from Antarctica, a partial solar eclipse will be visible from Australia. A partial solar eclipse will be visible for parts of North America on October 23, 2014. A total solar eclipse will be visible in the north Atlantic on March 20, 2015 (Europe and parts of Africa and Asia will be able to see a partial solar eclipse at that time).

For more details, and maps with times and locations for eclipse visibility, go to *eclipse.gsfc.nasa.gov/eclipse.html*.

Barringer Grant Applications for 2014 Now Being Accepted

This year's application deadline for grants from the Barringer Family Fund for Meteorite Impact Research is April 4, 2014. This program provides three to five competitive grants each year in the range of $2500 to $5000 USD for support of field research at known or suspected impact sites worldwide. Grant funds may be used to assist with travel and subsistence costs, as well as laboratory and computer analysis of research samples and findings. Masters', doctoral, and post-doctoral students enrolled in formal university programs are eligible. For additional details and an application, visit *www.lpi.usra.edu/science/kring/Awards/Barringer_Fund*.

Jet Propulsion Laboratory Summer Faculty Research Program

Applications are currently being accepted for NASA's Jet Propulsion Laboratory 2014 Summer Faculty Research Program. This program provides opportunities for science, technology, engineering, and mathematics (STEM) faculty to engage in research of mutual interest to the faculty member and a JPL researcher. Non-STEM faculty will be considered based on available opportunities. To be eligible to participate in the program, a potential fellow must hold a full-time appointment at an accredited university or college in the U.S. Special requirements for foreign national faculty members may apply. Fellows are required to submit a research report and present their work at the end of the session.

The program awards $13,500 fellowships for the 10-week session. A housing allowance will be offered for awardees who live beyond a 50-mile radius of JPL. Please note that stipend payments or salaries from other federal funding sources, including research grants and contracts, may not be accepted during the 10-week tenure of a JPL faculty research appointment. The deadline for applications is April 1.

For more information about this opportunity, visit *jsfrp.jpl.nasa.gov*. Inquiries about NASA's JPL Summer Faculty Research Program should be directed to Petra Kneissl-Milanian at *Petra.A.Kneissl-Milanian@jpl.nasa.gov*.

Earth and Space Science Newsletters for Educators

NASA Science Mission Directorate has a monthly newsletter that includes upcoming educational programs, events, opportunities, and the latest resources, sent by e-mail and available online at *www.smdeponews.org*. Links are available to access newsletter archives or to subscribe.

The Lunar and Planetary Institute also has a monthly newsletter available online at *www.lpi.usra.edu/education/resources/news* that also incorporates Earth and space science educational programs, events, grants, and more from both NASA and non-NASA sources.

Submit to be Part of the OSIRIS-REx Mission to an Asteroid and Beyond

NASA invites the general public to submit their names to be etched on a microchip onboard the Origins-Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) spacecraft, headed to the asteroid Bennu in 2016. The "Message to Bennu!" microchip will travel onboard the spacecraft, which will spend more than two years at the asteroid, collecting a sample of Bennu's surface and returning it to Earth in a sample return capsule. Those submitting their names for inclusion in the mission will be able to download and print a certificate documenting their participation. Submissions are due September 30. For more information and to submit your name, visit *bit.ly/1hOCTRd*.

ASP Annual Meeting: Celebrating Science: Putting Education Best Practices to Work

The Astronomical Society of the Pacific's 2014 Annual Meeting will be held August 4–6, 2014, at the Hyatt Regency in Burlingame, California, just south of San Francisco. More information is available at *www.astrosociety.org/education/asp-annual-meeting*.

Thomas Pierson, 1950–2014

Thomas Pierson, who founded the SETI Institute and went on to become its Chief Executive Officer for most of the organization's first 30 years, died on February 20 of cancer. He had been on medical leave since 2012.

Under Pierson's guidance, the Institute grew from a tiny, narrowly focused research center with a handful of employees to its current status: an internationally known organization that is home to more than 130 scientists, educators, and support staff. While founded to conduct SETI (search for extraterrestrial intelligence) searches, the Institute soon broadened its mandate to encompass all aspects of understanding the nature and prevalence of life beyond Earth.

Growing up in Norman, Oklahoma, Pierson studied aerospace engineering at the University of Oklahoma. By the early 1980s, Pierson was working as a grants administrator at San Francisco State University where he helped adjunct Professor Charles Seeger obtain research funds for the new SETI project headquartered at NASA Ames Research Center, an hour's drive to the south. Intrigued, he made a proposal to project participants Barney Oliver, John Billingham, and Jill Tarter, suggesting a more efficient way to organize the NASA efforts. Pierson laid out the benefits — both organizational and financial — of setting up a nonprofit entity, dedicated to the research. In this way, the administrative and other costs associated with the project could be kept low, and more of the budgeted monies could go to the science. Finding broad agreement with his idea, Pierson completed the paperwork in the fall of 1984, at which point the SETI Institute became a reality.

A decade later, the existence of this nonprofit organization became crucially important in saving the nation's largest SETI program. In 1993, a Senate amendment canceled funding for NASA SETI, and the Institute stepped into the breach to keep the research going with private funding. Over the course of the last two decades, these efforts raised approximately $90 million in private monies from donors such as Oliver, Paul Allen, Gordon Moore, Bill Hewlett, and David Packard, making possible the construction of the Allen Telescope Array, now used for the Institute's SETI searches. Today, monies won by its scientists in competitive solicitations generate approximately $17 million annually for astrobiology research.

For his extensive contributions to furthering the field of astrobiology, Pierson was recently recognized with NASA's Distinguished Public Service Award, the highest honor given by the agency to nongovernment employees. The citation reads: "For distinguished service to NASA and the scientific community through leadership of the SETI Institute, supporting basic research and education dealing with life in the universe."

Pierson was not a scientist, but he was as fervent about the Institute's varied research agenda as any of its investigators. He would exuberantly convey the excitement of SETI and astrobiology at any gathering, professional or amateur, formal or casual. His management style was characterized by a fierce loyalty to the Institute's employees, and an easy willingness to let them try new ideas. The persona and personality of Pierson continues to define the organization that he founded, and his enthusiasm, upbeat attitude, sense of humor, and humility are the organization's DNA. He was always pleased to let his employees take the

credit for any of the Institute's many accomplishments. And yet those who had the great fortune to work here during the nearly three decades of his tenure know that their work and their rewards were made possible by Pierson. The SETI Institute remains a burnished legacy of the man who conjured its existence.

— Text and photo courtesy of the SETI Institute

NASA Researchers Receive Presidential Early Career Award

U.S. President Barack Obama named five NASA researchers on December 23 as recipients of the 2012 Presidential Early Career Award for Scientists and Engineers (PECASE). These recipients and 97 other federal researchers will receive their awards in a ceremony in Washington.

President Barack Obama addresses 2011 Presidential Early Career Awards for Scientists and Engineers (PECASE) recipients in the East Room of the White House, July 31, 2012. Credit: Official White House Photo by Pete Souza.

The PECASE awards represent the highest honor bestowed by the U.S. government on scientists and engineers beginning their research careers. The award recognizes recipients' exceptional potential for leadership at the frontiers of scientific knowledge and their commitment to community service as demonstrated through professional leadership, education, or community outreach. "These early career scientists and engineers represent some of the best and brightest talent in our agency and our university partners," said NASA Chief Scientist Ellen Stofan. "We are delighted to see them win this prestigious award. Their contributions, ranging from microgravity and space radiation effects, X-ray spectrometry, advanced composites, remote sensing, and climate research, will benefit our nation and advance the scientific frontiers."

The recipients were nominated by the agency's Science Mission Directorate, Office of the Chief Engineer, and Office of the Chief Technologist. The recipients are Dr. Joshua S. Alwood, at NASA's Ames Research Center, for research into the temporal changes in skeletal tissue density, cancellous orientation, and vasculature during recovery from musculoskeletal disuse; Dr. Douglas C. Hofmann, at NASA's Jet Propulsion Laboratory, for his innovative research in metal-matrix composites for future NASA missions; Dr. Randall L. McEntaffer, at the University of Iowa, Iowa City, for development of high-resolution and high-throughput X-ray gratings for use in the next generation of space-based X-ray spectrometers; Dr. Tamlin M. Pavelsky, at the University of North Carolina, Chapel Hill, for outstanding research and leadership advancing satellite remote sensing of river discharge, including enabling the broader community to develop and improve algorithms for Surface Water Ocean Topography (SWOT), a future NASA satellite being developed by JPL; Dr. Patrick C. Taylor, at NASA's Langley Research Center, Hampton, Virginia, for exceptional early career achievements and innovations that have advanced scientific understanding of Earth's climate system.

The PECASE awards were created to foster innovative developments in science and technology, increase awareness of careers in science and engineering, give recognition to the scientific missions of participating agencies, enhance connections between fundamental research and many of the grand challenges facing the nation, and highlight the importance of science and technology for America's future. For a complete list of award winners, visit *www.whitehouse.gov/the-press-office/2013/12/23/president-obama-honors-outstanding-early-career-scientists*.

LPI Announces 2014 Career Development Award Winners

The Lunar and Planetary Institute (LPI) is proud to announce the winners of the seventh LPI Career Development Award. The award is given to graduate students who submitted a first-author abstract to the 45th Lunar and Planetary Science Conference (LPSC). The awards are based on a review of the application materials by a panel of planetary scientists, and recipients will receive an $1000.00 travel stipend to help cover their expenses for attending the conference.

The 45th LPSC will be held at The Woodlands Waterway Marriott Hotel & Convention Center in The Woodlands, Texas. Approximately 2000 participants from all over the world are expected to gather for the annual meeting, which has gained the reputation of being the premiere gathering place for lunar and planetary scientists. The meeting provides an invaluable opportunity for students, not only to present their own research, but also to hear and see firsthand the latest-breaking results from other researchers in their field. Opportunities are also provided for students to meet and network with an international group of distinguished researchers.

Congratulations to the 2014 recipients: Elena Amador (University of Washington, United States); Subramania Athiray (University of Calicut, India); Jessica Barnes (The Open University, United Kingdom); Patricio Becerra (The University of Arizona, United States); Elizabeth Frank (University of Colorado, United States); Rebecca Greenberger (Brown University, United States); Pierre Haenecour (Washington University in St. Louis, United States); Mohit Melwani Daswani (The Open University, United Kingdom); Rebecca Mickol (University of Arkansas, United States); Wladimir Neumann (Westfälische Wilhelms-Universität Münster, Germany); Marc Neveu (Arizona State University, United States); Corliss Kin I Sio (The University of Chicago, United States); Michelle Thompson (The University of Arizona, United States); and Diane Wetzel (Brown University, United States).

DPS 2013 Prize Recipients

The Division of Planetary Sciences (DPS) of the American Astronomical Society recently announced its 2013 prize recipients.

Gerard P. Kuiper Prize: Joseph Veverka

The 2013 Gerard P. Kuiper Prize for outstanding contribution to planetary science has been awarded to Dr. Joseph Veverka. Veverka is a professor Emeritus at Cornell University and the former James A. Weeks Professor of Physical Sciences and Professor of Astronomy. He has made outstanding contributions to the field of planetary science during a career that now spans five decades, and has to his credit a lifetime of outstanding contributions, that, in sum, represent a monumental increase in our understanding of planets and, in particular, small bodies — the moons, asteroids, and cometary nuclei in our planetary system. His research has helped to bring attention to the importance of small bodies in providing clues to the processes that formed our solar system, and coordinated the efforts to obtain the first close-up images of an asteroid (951 Gaspra). Veverka was also instrumental in advancing the field of photometry as a means of characterizing the composition and texture of planetary surfaces. His contributions to the geologic

study of satellites, asteroids, and comets are extensive, and he has also conducted research on planetary ring systems and Titan's atmosphere. In addition, through exceptional service to the community, he has also found time to shape many aspects of the U.S. program of robotic solar system exploration as we know it today. As a professor at Cornell, he mentored and provided a formative influence on his students and research associates, many of whom have gone on to highly successful careers in planetary science, including Bonnie Buratti, Jay Goguen, Steve Lee, Linda French, Steve Squyres, Damon Simonelli, Pascal Lee, Anne Verbiscer, and Peter Thomas.

Harold C. Urey Prize: Anders Johansen

The 2013 Harold C. Urey Prize for outstanding achievement in planetary research by a young scientist has been awarded to Dr. Anders Johansen. Johansen is currently Associate Senior Lecturer at the University of Lund in Sweden. His work on planetesimal accretion and more recently on giant planet core formation has provoked paradigm shifts in a field that for years had been plagued by long-standing problems. By filling not one but two major gaps in one of the most difficult area of solar system studies, Johansen's findings represent one of the most significant contributions to the field since the pioneering works of Safronov and Wetherill. His achievements have been the combined result of imagination, technical skill, and a deep knowledge of diverse relevant fields, ranging from hydrodynamical simulations to meteorite cosmochemistry.

Harold Masursky Award: Ronald Greeley

The 2013 Harold Masursky Award for outstanding service to planetary science and exploration to has been awarded posthumously to Dr. Ronald Greeley. Greeley was a Regents' Professor of Planetary Geology at Arizona State University until his death in 2011. He was one of the founders of the field of planetary geology and early on recognized that understanding the processes and histories of solar system bodies required integration of field, laboratory, modeling, and observational studies. Greeley's research focused on volcanic and aeolian processes on Earth and other planetary bodies, and he was also a specialist in geologic mapping from planetary images. He served as the founding director of the NASA-ASU Regional Planetary Image Facility and Principle Investigator of the Planetary Aeolian Laboratory at NASA Ames, and served on and chaired many NASA and National Academy of Sciences definition teams and study groups to assess space science and planetary geology activities. Greeley was also involved in nearly every major space probe mission flown in the solar system since the Apollo missions to the Moon, including the Galileo mission to Jupiter, Magellan mission to Venus, Voyager 2 mission to Uranus and Neptune, and Shuttle Imaging Radar orbiter around Earth. Passionate about Mars exploration, he was involved with numerous missions to the Red Planet, including Mariners 6, 7, and 9, Viking, Mars Pathfinder, Mars Global Surveyor, and the Mars Exploration Rovers. He was a co-investigator for the High Resolution Stereo Camera on the European Mars Express mission. Among his final projects were service as the chair of the Planetary Science Subcommittee of the NASA Advisory Council and co-chair of various Science Definition Teams for Europa Orbiter mission concepts. His work lives on in his former students and colleagues who work and teach in the planetary sciences and play pivotal roles in space science efforts.

Carl Sagan Medal: Donald K. Yeomans

The 2013 Carl Sagan Medal for excellence in public communication has been awarded to Dr. Donald Yeomans. The inevitability of collisions between asteroids and Earth is a topic that naturally engages public interest. Systematic searches have turned up an increasing number of "near misses," or objects with statistically small, but non-zero, probabilities of a future impact within the uncertainties of existing

observations. The urgency of these events is amplified by actual impacts such as the Chelyabinsk bolide in February 2013. For more than two decades, Yeomans has been the "go to" person whenever the media seek a planetary scientist to illuminate the scientific middle ground between the hype and the ho-hum. Yeomans has capitalized on his roles as manager of the NASA Near Earth Object (NEO) Program Office at JPL and a Co-I on the Deep Impact mission to build a lengthy resume of media appearances, outreach events, and popular press contributions. His calm demeanor and scientific rigor have helped to dampen doomsday hysteria and sound the all-clear on more serious potential risks (e.g., Apophis) when improved observations warrant. And in every case, he takes the opportunity to educate the public on the real long-term risks and potential benefits of NEOs.

He is a prolific author with more than 160 professional publications and numerous writings in the popular press. He has authored five books, most recently his 2012 work, *NEOS: Finding Them Before They Find Us*. His recognized expertise has led to multiple invitations to speak to not only the general public, but also to Congressional representatives and staff. In February 2013 he testified for NASA to the United Nations Committee on the Peaceful Uses of Outer Space only days after the dramatic Chelyabinsk bolide shook the world to attention. In recognition of the importance of Yeomans' role, he was recently named one of the 100 Most Influential People in the world by *TIME* magazine.

Jonathan Eberhart Planetary Sciences Journalism Award: Richard A. Kerr

Dr. Richard A. Kerr is a journalist who has spent his entire professional career covering Earth and planetary science news for *Science* magazine. His audience? More than 100,000 world-class experts in science — but not necessarily expert in the kind of science he writes about. It's a challenging beat, because his readers are knowledgeable, savvy, and skeptical. Since science papers often come with a backstory that he frequently reviews in his articles, he must analyze and critique the quality of the work on its own merits and put it into context for the field. Kerr wrote in *A Field Guide for Science Writers:* "If, as veteran *San Francisco Chronicle* science reporter David Perlman once wrote, science writing is a continuing graduate education, then writing for scientists is a Ph.D. in science news reporting." Kerr originally planned to be a meteorologist, but found calculus an obstacle, and ended up studying chemistry at the College of Wooster. Following two deployments in the navy during the Vietnam War, he did his Ph.D. in oceanography at the University of Rhode Island (URI). While at URI, he "surreptitiously" took two night classes in magazine story writing and news reporting — his entire formal training in journalism. A fellow student told him about the job opening as a writer for *Science* magazine, where he was hired one week after defending his dissertation, and where he has been ever since — 36 years. Many of us have had the pleasure of answering Kerr's knowledgeable, incisive questions, but he is able to ask intelligent questions of fields ranging from asteroids striking Earth to weather on Mars. Kerr's education has continued throughout his career, through exhaustive reading of publications, bulletins, and abstract volumes, and through attendance at Earth and planetary science conferences. Kerr has an enviable skill for picking newsworthy stories out of voluminous abstract volumes, and for injecting a carefully calibrated quantity of skepticism into his reports on the most sensational discoveries. He is the recipient of numerous awards because of his exceptional service to science journalism. One testament to his unflagging effort to promote planetary sciences though *Science* is the 2012 article entitled "Peering Inside the Moon to Read its Earliest History." The article focuses on the violent impact history of our Moon as observed by the GRAIL mission. For this engaging and stimulating article, the Division for Planetary Sciences is pleased to present the 2013 Jonathan Eberhart Planetary Sciences Journalism Award to Dr. Richard A. Kerr.

Elon Musk Wins National Space Society Robert A. Heinlein Award

The National Space Society (NSS) takes great pleasure in announcing that its 2014 Robert A. Heinlein Memorial Award has been won by acclaimed space entrepreneur Elon Musk, the Chief Designer and CTO of SpaceX. In the last decade, SpaceX, under the leadership of Musk, has been moving directly toward accomplishing goals that are of utmost importance, such as forcing a drastic reduction in launch costs by doing the task that no one else in the world has been willing and able to tackle: working to create a family of commercially successful and reusable rocket boosters and reusable spacecraft.

The dreams of our visionaries of the last 100 years will not be fulfilled until affordable, large-scale, high-mass operations can take place in Earth orbit and beyond. SpaceX's Dragon spacecraft is reusable, and SpaceX is making great progress toward developing a reusable rocket, the key development that would make such operations possible.

Musk was born in South Africa in 1971 and emigrated first to Canada and then to the U.S. He has two B.A. degrees, one in physics and one in economics, from the University of Pennsylvania. Musk became a multimillionaire in his late twenties when he sold his start-up company, Zip2, to a division of Compaq Computers, and went on to more early successes, launching PayPal via a 2000 merger. He founded Space Exploration Technologies Corporation (SpaceX) in 2002, the same year that he became an American citizen and the same year he earned the money to fund the new company from the sale of PayPal. The SpaceX Falcon 1 was the first privately funded liquid fueled rocket to put a payload into orbit. The larger Falcon 9 rocket has been flying since June 2010, and SpaceX is also developing a reusable version called Falcon 9R and a much larger rocket, Falcon Heavy. SpaceX has a 1.6-billion-dollar contract with NASA to supply the space station via its recoverable Dragon spacecraft, and is also a competitor in NASA's Commercial Crew Program.

Musk views space exploration as important for the preservation and expansion of humankind. He likes to say that we should become "multiplanetary" as a hedge against all threats to our survival. "Sooner or later, we must expand life beyond this green and blue ball — or go extinct." To help make that happen, Musk's goal is to reduce the cost of human spaceflight by a factor of 100.

The award will be presented to Musk at the 2014 International Space Development Conference (ISDC), which will be held in Los Angeles, California, in May. The Heinlein award is presented once every two years for lifetime achievement in promoting the goal of a free, spacefaring civilization. Previous winners include Sir Arthur C. Clarke and Dr. Carl Sagan. More information about this award is available at *www.nss.org/awards/heinlein_award.html*.

Telescope Named After Senator Daniel Inouye

Artist's rendering of the Daniel K. Inouye Solar Telescope on Haleakalā. Credit: Tom Kekona, K.C. Environmental, Inc.

The National Science Foundation (NSF) and the Association of Universities for Research in Astronomy (AURA) have renamed the Advanced Technology Solar Telescope under construction in Maui, Hawaii, the Daniel K. Inouye Solar Telescope. The name memorializes the late senator's profound commitment to fundamental scientific research and discovery, particularly in astronomy.

When completed in 2019, the Inouye telescope will be the world's premier groundbased solar observatory — more powerful than any other in the world. Armed with this new instrument, astronomers will be equipped to glean new insights into solar phenomena and discover new information for understanding how our nearest star works, and for protecting the nation's vital spacebased assets, the power grid, and communication and weather satellites.

The four-meter aperture of this instrument being constructed on Haleakalā is unprecedented for a solar telescope. It will be able to provide incomparable data that allow researchers to see more clearly into the heart of sunspots, flares, and other manifestations of solar activity. It will be the premier groundbased platform where academics, industry, NASA centers, and other national and international partners can collaborate to answer challenging questions of global impact. Befitting the legacy of Inouye, the telescope will be pivotal in training the next generation of solar physicists and instrument builders as it hosts undergraduate and graduate opportunities and imparts curriculum development for local schools.

"Over five decades of national public service, Senator Inouye was a strong proponent of American science and innovation," said NSF Acting Director Cora Marrett. "This remarkable facility in his beloved state of Hawaii will expand our knowledge and advance our nation's scientific leadership over many decades to come."

AURA, which operates the National Solar Observatory on the site of the University of Hawaii's Haleakalā Observatory, is building and will operate this NSF-owned, state-of-the-art instrument. The Inouye telescope is located on the summit of Haleakalā, an important site sacred to Native Hawaiian people, and the use of this site, in consultation with the Native Hawaiian Working Group, is gratefully acknowledged. For more information about the telescope, visit *atst.nso.edu*.

NASA Honors Astronaut Neil Armstrong with Center Renaming

Two generations of aerospace engineering excellence came together on Saturday, March 1, when NASA's Dryden Flight Research Center in Edwards, California, was redesignated NASA's Armstrong Flight Research Center. The agency's center of excellence for atmospheric flight research is being renamed in honor of the late Neil A. Armstrong, a former research test pilot at the center and the first man to step on the Moon during the historic Apollo 11 mission in 1969. The late Hugh L. Dryden, the center's namesake since 1976, will continue to be memorialized in the renaming of the center's 12,000-square-mile Western Aeronautical Test Range as the Dryden Aeronautical Test Range.

"I cannot think of a more appropriate way to honor these two leaders who broadened our understanding of aeronautics and space exploration," said NASA Administrator Charles Bolden. "Both Dryden and Armstrong are pioneers whose contributions to NASA and our nation still resonate today. Armstrong was the first person to walk on the Moon. Dryden's expertise at the National Advisory Committee for Aeronautics and then at NASA established America's leadership in aerospace, and his vision paved the way for Armstrong to take those first steps."

The redesignation of the center, which is located on Edwards Air Force Base in Southern California, was directed in legislation authored by Rep. Kevin McCarthy of California's 22nd district. The resolution was passed unanimously by the U.S. House of Representatives in early 2013, with the Senate concurring in early January, followed by President Obama's signing it into law on January 16.

Armstrong had significant ties to the center, both before and after his days as a NASA astronaut. He served as a research test pilot at the center from 1955 to 1962, amassing more than 2400 flight hours in 48 different models of aircraft at the center, including seven flights in the rocket-powered hypersonic X-15. Armstrong was part of a team that conceptualized the Lunar Landing Research Vehicle, a flight test craft that evolved into the Lunar Landing Training Vehicle. Armstrong and the other commanders of Apollo lunar landing missions trained in that vehicle for their descents from lunar orbit down to the surface of the Moon. Following Apollo 11, Armstrong left the astronaut corps and became NASA's Deputy Associate Administrator for Aeronautics, overseeing aeronautical research programs being conducted at the center, particularly its pioneering work on developing digital electronic flight control systems.

Dryden, considered an aeronautical engineering genius, focused on high-speed flight during his tenure as an aeronautical scientist with the National Bureau of Standards. Involved in NACA research from his doctoral research days, Dryden's first NACA Technical Report was published in 1924, and after World War II he moved from the Bureau of Standards to take charge of the NACA in 1947. Under his deft leadership, the NACA rapidly pushed the boundaries of high-speed flight and organized the research that led to our first steps into space. Dryden continued with the agency after NACA became NASA in late 1958, serving as deputy administrator of NASA until his death in 1965. Dryden's quiet but visionary leadership of the NACA is what prepared that organization to become NASA in 1958, and to have

an achievable plan for a human expedition to the Moon when President John F. Kennedy called for it in 1961. The organizational genius of Dryden was at the root of Armstrong's most spectacular flight achievements, from the X-15 to Tranquility Base.

The renaming of a NASA center is not without precedent. In 1999, the Lewis Research Center in Cleveland was renamed in honor of Sen. John Glenn, the first American to orbit the Earth in the Friendship 7 Mercury capsule in 1962. A formal public ceremony to mark the redesignation of the center and its test range is planned for this spring.

NASA Observatory Selects Educator Teams for 2014 Science Flights

NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) will become a flying classroom for teachers during research flights in the next few months. Twelve two-person teams have been selected for SOFIA's Airborne Astronomy Ambassadors program, representing educators from 10 states. Each will be paired with a professional astronomer to observe firsthand how airborne infrared astronomy is conducted. After their flight opportunities, Airborne Astronomy Ambassadors will take what they learn back to their classrooms and into their communities to promote science literacy.

SOFIA is a highly modified Boeing 747SP jetliner fitted with a 100-inch (2.5-meter) effective diameter telescope. The aircraft flies at altitudes between 39,000 and 45,000 feet (12–14 kilometers), above the water vapor in Earth's atmosphere, and collects data in the infrared spectrum. "SOFIA offers educator teams unprecedented access to infrared astronomers and the unique capabilities of an airborne observatory," said John Gagosian, SOFIA program executive at NASA Headquarters in Washington. "Previous Airborne Astronomy Ambassadors teams have witnessed SOFIA's world-class astronomical science and have used this experience in hundreds of science, technology, engineering and math teaching opportunities throughout the United States."

SOFIA's Airborne Astronomy Ambassadors for 2014 are Megan Tucker and Dan Molik, The Palmdale Aerospace Academy, Palmdale, California; Barbel Sepulveda, Lincoln High School, and Chris Rauschenfels, Sierra Middle School, Stockton, California; Nathan Mahoney, Pine Crest School, Deerfield Beach, Florida, and Héllen Tavora, South Florida Amateur Astronomers Association and Fox Astronomical Observatory, Fort Lauderdale, Florida; Marcella Linahan, Carmel Catholic High School, Mundelein, Illinois, and Lynne Zielinski, National Space Society, Long Grove, Illinois; Judi Little and LeeAnn Vaughan, Burke High School, Omaha, Nebraska; Margaret Holzer, Chatham High School, Somerset, New Jersey, and Theresa Roelofsen Moody, New Jersey Astronomy Center at Raritan Valley Community College, High Bridge, New Jersey; Michael Maccarone and Elizabeth Rosenberger, Avenues: The World School, Hoboken, New Jersey; Tom Jenkins, Dayton Regional STEM Center, Enon, Ohio, and Heidi Steinbrink, Oakwood Senior High School, Springfield, Ohio; Robert Black, North Medford High School, and Dave Bloomsness, Southern Oregon Skywatchers, Medford, Oregon; George Hademenos

and Diane Watson, Richardson High School, Richardson, Texas; Kim Abegglen and Anna-Melissa Lyons, Hockinson Middle School, Vancouver, Washington; and Kathy Gustavson, Nicolet High School, Whitefish Bay, Wisconsin, and Jean Creighton, University of Wisconsin–Madison, Manfred Olson Planetarium, Milwaukee, Wisconsin.

"Educators are selected through a rigorous peer-reviewed process for this yearly professional development opportunity," said astronomer Dana Backman, manager of SOFIA's education and public outreach programs at NASA's Ames Research Center. "To date, the Airborne Astronomy Ambassadors' program has flown 15 teams totaling 31 educators from 17 states, and we look forward to working with this new cadre of educators as they take NASA science into their communities."

SOFIA is a joint project of NASA and the German Aerospace Center (DLR). The aircraft is based at the Dryden Aircraft Operations Facility in Palmdale, California. NASA's Dryden Flight Research Center (now called the Armstrong Flight Research Center) in Edwards, California, manages the program. Ames manages the SOFIA science and mission operations in cooperation with the Universities Space Research Association (USRA) in Columbia, Maryland, and the German SOFIA Institute (DSI) at the University of Stuttgart.

For more information about SOFIA, visit *www.nasa.gov/sofia*, *www.dlr.de/en/sofia*, or *www.sofia.usra.edu*.

Grand Opening of UCLA Meteorite Gallery

Canyon Diablo, a meteorite that struck Arizona ~50,000 years ago, is the centerpiece of the UCLA Meteorite Galley.

California's largest collection of meteorites, and the fifth-largest collection in the nation, is on display in the new UCLA Meteorite Gallery, which is free to the public. The museum, located in UCLA's Geology Building (Room 3697), is open weekdays from 9:00 a.m. to 4:00 p.m. and on some weekend afternoons.

Canyon Diablo, a meteorite that struck Arizona ~50,000 years ago, is the centerpiece of the UCLA Meteorite Galley.

A centerpiece of the museum is a 357-pound iron chunk of an asteroid that crashed into Arizona some 50,000 years ago, creating a mile-wide crater just east of Flagstaff. Visitors are allowed to touch the venerable object, which like most other meteorites and like Earth itself is 4.5 billion years old, said John Wasson, the gallery's curator and a professor of geochemistry and chemistry in the UCLA College of Letters and Science.

The collection houses specimens of nearly 1500 meteorites that illustrate the scientific processes that were active in the early solar system. About 100 of these — representing a wide variety of meteorite types — are currently on display.

These include chondrites, which contain large numbers of tiny rocky spherules known as chondrules. The origin of chondrules remains very much a mystery. It appears they were created from clumps of dust in the solar nebula — the gas and dust cloud that existed before planets and asteroids formed — and were "zapped" in a way that is still unknown. The gallery's images of primitive chondritic meteorites taken with a scanning electron microscope offer detailed views of chondrules.

The museum also features backlit samples of a class of beautiful meteorites called pallasites, which contain silicate minerals mixed with metal. These specimens formed at the "interface between the metallic core and the silicate mantle" of an asteroid, Wasson said. "We have no sample of the core of any of the planets or even a major moon, but many of the iron meteorites are samples of an asteroid's core, and they differ from one another."

Wasson, a member of UCLA's faculty since 1964, has devoted his scientific career to studying meteorites. "Meteorites are fragments that were, in part, the building blocks of the planets," he said. "Many of these are the first rocks that formed anywhere in the solar system. They have information about the earliest history of the solar system that we cannot learn from the Earth itself."

One of the gallery's exhibits explains how to correctly identify meteorites. Detailed explanations of the samples are provided in display cases and brochures. Alan Rubin, the associate curator of the gallery and a researcher in UCLA's Department of Earth, Planetary and Space Sciences, is an expert in identifying meteorites. He receives samples every few days from people who believe they have found meteorites. "They almost never are real meteorites," he said, adding that "less than 1%" actually come from beyond the Earth. Some of these objects mistaken for meteorites — including ordinary rocks, petrified wood, and metal slag — are on display in an exhibit aptly titled "meteorwrongs."

"For many years, we've collected beautiful exhibit specimens of meteorites but kept them locked in inaccessible cabinets," Rubin said. "It's great to be able to put them out on display for people to see." UCLA's collection of meteorites has grown to nearly 3000 specimens under the stewardship of Wasson and Rubin, and is among the most extensive in the world.

The UCLA Meteorite Gallery's grand opening was held on January 10 and honored Arlene and Ted Schlazer, who donated more than 60 exhibit-worthy meteorites to UCLA, as well as a bequest for an endowed chair in cosmochemistry and meteorite research. The Meteorite Gallery is supported by UCLA's Department of Earth, Planetary and Space Sciences and Institute for Planets and Exoplanets.

NASA Ranked Best Place to Work in Government for Second Year in a Row

For the second year in a row, NASA was named the best place to work in the federal government among large agencies in a survey released in December by the Partnership for Public Service, a nonprofit, nonpartisan organization. Following the announcement, NASA Administrator Charles Bolden issued the following statement:

"NASA's selection as the Best Place to Work in Government for the second year in a row is a testament to the excellence of our workforce and their determination to maintain America's leadership in space exploration. In a year of budget uncertainty and a government shutdown, NASA employees never missed a beat. In the tradition of the 'can do' spirit that has enabled us for more than 50 years to turn science fiction into science fact, they have consistently rolled up their sleeves and worked hard at achieving our major goals, which include leading the expansion of a domestic commercial space industry for low-Earth orbit transportation, and developing a heavy lift launch capability to take humans farther than they have ever explored — to an asteroid in the next decade and to Mars by the 2030s. Our employees are also focused on continuing our ambitious programs of aeronautics modernization, technological innovation, and scientific and planetary exploration to achieve new breakthroughs in space and to bring critical benefits to Earth. I am honored and proud to lead such a dedicated team of employees. They are what make NASA the best place to work in government."

For the complete list of rankings, visit *bestplacestowork.org*.

NASA iPad Application Shows Earth Changing Before Your Eyes

Human activities, a changing climate, and natural disasters are rapidly altering the face of our planet. Now, with NASA's Images of Change iPad application, users can get an interactive before-and-after view of these changes. The app presents sets of images of places around the world that have changed dramatically. Some of these locations have suffered a disaster, such as a fire or tsunami, or illustrate the effects of human activities, such as dam building or urban growth. Others document impacts of climate change such as persistent drought and rapidly receding glaciers.

NASA Administrator Charles Bolden explores "Images of Change," a NASA application that allows users to view "before and after" images of the impact of human activities, a changing climate and natural disasters on Earth. Credit: NASA/Bill Ingalls.

"Images of Change gives users an astronaut's or Earth explorer's view of the changes occurring on our planet and demonstrates the important role NASA plays in contributing to the long-term understanding of Earth," said John Grunsfeld, NASA's associate administrator for science in Washington. "By utilizing groundbased and spacebased observation systems, we are able to better understand how humans are contributing to a changing world."

Images of Change makes NASA climate change resources, images, and interactive tools more accessible to citizens and decision makers, a key aspect of President Obama's Climate Action Plan. The image pairs are part of the larger Images of Change gallery on NASA's Webby-award-winning Global Climate Change website. The gallery includes satellite views as well as photos taken at ground level. Viewers can look at the images side-by-side or overlay them using a slider bar to travel from past to present. Each image pair includes background information on what the viewer is seeing and its location on a map.

"The Images of Change gallery is one of the more popular parts of the Global Climate Change website," said Amber Jenkins, editor of the website at NASA's Jet Propulsion Laboratory. "The gallery project, which began in 2009, helps people see just how our planet is changing over days, months, years, and centuries. Seeing is believing, and the perspective we get from space helps us step back and see Earth as a whole." The Images of Change iPad app is available as a free download at *go.nasa.gov/1bE3osn*. For more information on NASA's contributions to climate science, visit *climate.nasa.gov*.

SkyCube: The First Crowd-Funded Satellite

Space app developer Southern Stars has built a nanosatellite called SkyCube that launched into orbit on January 9, 2014. SkyCube was financed by thousands of sponsors and mobile app users around the world. It is a global grass-roots public outreach and educational effort whose purpose is to make space exploration accessible as never before. An Orbital Sciences Antares rocket took the SkyCube satellite to the International Space Station (ISS), to be deployed into orbit by early March.

SkyCube is a tiny CubeSat, 10 centimeters on each side. It contains three miniature cameras, a 915-Mhz radio transmitter, and a tightly packed balloon. After deployment, Satellite Safari app user requests for images and "tweets" from space will be collected by Southern Stars, then relayed to the satellite by the Mobile CubeSat Command and Control (MC3) network, headquartered at the Naval Postgraduate School in Monterey, California, and by Saber Astronautics in Sydney, Australia.

After a 2–3-week "shakeout" period following deployment, SkyCube public mission operations will begin. The satellite will let users send simple broadcasts — "tweets from space" — that amateur radio operators around the world can hear, and anyone with a smart phone can follow. Users will be able to request images of Earth from the cameras onboard the satellite, using the Satellite Safari app on their iOS or Android device. "SkyCube lets anyone broadcast their own messages from space and take photos of Earth from orbit with a simple app," said Astronomers Without Borders CEO Mike Simmons. "This is a space enthusiast's dream."

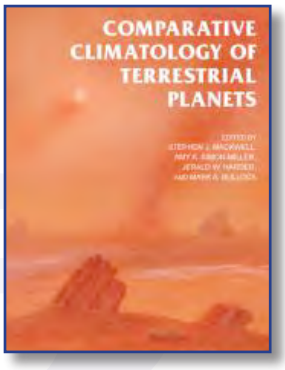
At the end of its 90-day mission, SkyCube will inflate the onboard balloon to deorbit itself two weeks later. The balloon will make SkyCube visible to the thousands of people around the world who have

sponsored and followed the mission. And it will prevent SkyCube from becoming space debris: When the satellite reenters the atmosphere, like a meteor, it will vaporize cleanly.

"Unlike any other satellite launched to date, SkyCube was was built by a small group of Silicon Valley engineers working on their spare time, and financed through crowd-funding and the sale of mobile apps," said SkyCube project creator Tim DeBenedictis. "It's not financed by government agency, aerospace corporation, or university. We're not a large corporation, and we're not NASA. We're a bunch of geeks who decided to make their dreams happen."

Southern Stars Group, LLC, headquartered in San Francisco, is a world leader in mobile applications for astronomy, and has been developing planetarium software since 1993. In 2009, Southern Stars developed SkyFi, the first wireless iPhone-based solution for telescope control. That product, and the first version of the SkySafari iPhone app, won a MacWorld 2010 Best of Show award. Southern Stars was the also the first company to ship a Made-for-iPad serial cable for iOS devices (SkyWire). To date, Southern Stars' iPhone apps have been downloaded more than 4 million times, and have earned five-star reviews on the app store and by independent reviewers. For more information, visit *southernstars.com*.

BOOKS



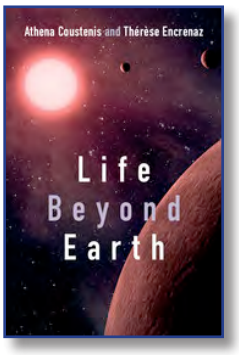
Comparative Climatology of Terrestrial Planets.

Edited by Stephen J. Mackwell, Amy A. Simon-Miller, Jerald W. Harder, and Mark A. Bullock. University of Arizona Press, 2013, 592 pp., Hardcover, $35.00. *www.uapress.arizona.edu*

The early development of life, a fundamental question for humankind, requires the presence of a suitable planetary climate. Our understanding of how habitable planets come to be begins with the worlds closest to home. Venus, Earth, and Mars differ only modestly in their mass and distance from the Sun, yet their current climates could scarcely be more divergent. Only Earth has abundant liquid water, Venus has a runaway greenhouse, and evidence for life-supporting conditions on Mars points to a bygone era. In addition, an Earth-like hydrologic cycle has been revealed in a surprising place: Saturn's cloud-covered satellite Titan has liquid hydrocarbon rain, lakes, and river networks. Deducing the initial conditions for these diverse worlds and unraveling how and why they diverged to their current climates is a challenge at the forefront of planetary science. Through the contributions of more than 60 leading experts in the field, *Comparative Climatology of Terrestrial Planets* sets forth the foundations for this emerging new science and brings the reader to the forefront of our current understanding of atmospheric formation and climate evolution. Particular emphasis is given to surface-atmosphere interactions, evolving stellar flux, mantle processes, photochemistry, and interactions with the interplanetary environment, all of which influence the climatology of terrestrial planets. From this cornerstone, both current professionals and most especially new students are brought to the threshold, enabling the next generation of new advances in our own solar system and beyond.

Life Beyond Earth. By Athena Coustenis and Thérèse Encrenaz.

Cambridge University Press, 2013. 287 pp., Hardcover, $29.99. *www.cambridge.org*

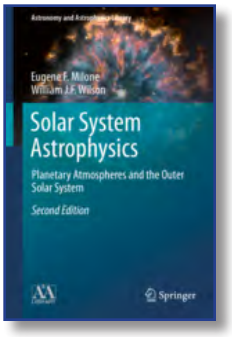


What is life and where can it exist? What searches are being made to identify conditions for life on other worlds? If extraterrestrial inhabited worlds are found, how can we explore them? In this book, two leading astrophysicists provide an engaging account of where we stand in our quest for habitable environments, in the solar system and beyond. Starting from basic concepts, the narrative builds scientifically, including more in-depth material as boxed additions to the main text. The authors recount fascinating recent discoveries from space missions and observations using groundbased telescopes, and of possible life-related artifacts in martian meteorites, extrasolar planets, and subsurface oceans on Europa, Titan, and Enceladus. They also provide a look forward to future missions. This is an exciting, informative read for anyone interested in the search for habitable and inhabited planets, and an excellent primer for students in astrobiology, habitability, planetary science, and astronomy.

GRAIL: Mapping the Moon's Interior.

Edited by Maria Zuber and Christopher Russell. Springer, 2014, 76 pp., Hardcover, $129.00. *www.springer.com*

In September 2011, the Gravity Recovery and Interior Laboratory (GRAIL) mission launched two unmanned spacecraft to the Moon, which entered into lunar orbit on December 31, 2011, and January 1, 2012. They orbited the Moon until December 17, 2012, when they impacted the surface near the Moon's north pole. This book contains three review articles co-authored by the GRAIL Science Team and guest scientists that describe the reasons for the GRAIL mission, the development of the necessary technology, and the design of the mission to acquire the most precise measurements of the lunar gravity field possible today. The book provides a detailed description of the GRAIL mission's scientific objectives, the instrumentation and its required performance, the complex simulation of the measurement system for determining the gravity field, and the innovative education and public outreach of the mission directed toward middle-school students who could select areas of the Moon for imaging with the onboard MoonKam camera system. This volume is aimed at researchers and graduate students active in solar system science and planetology.



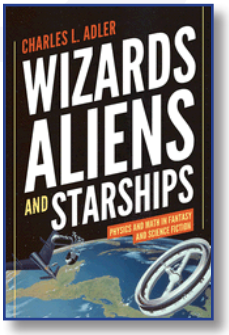
Solar System Astrophysics: Background Science and the Early Solar System, Second Edition.

By Eugene F. Milone and William J. F. Wilson. Springer, 2014, 364 pp., Hardcover, $99.00. *www.springer.com*

This second edition of *Solar System Astrophysics: Planetary Atmospheres and the Outer Solar System* provides a timely update of our knowledge of planetary atmospheres and the bodies of the outer solar system and their analogs in other planetary systems. This volume begins with an expanded treatment of the physics, chemistry, and meteorology of the atmospheres of Earth, Venus, and Mars, moving on to their magnetospheres and then to a full discussion of the gas and ice giants and their properties. From here, attention switches to the small bodies of the solar system, beginning with the natural satellites. Then comets, meteors, meteorites, and asteroids are discussed in order, and the volume concludes with the origin and evolution of our solar system. Finally, a fully revised section on extrasolar planetary systems puts the development of our system in a wider and increasingly well understood galactic context.

Wizards, Aliens, and Starships: Physics and Math in Science Fiction and Fantasy.

By Charles L. Adler. Princeton University Press, 2014, 392 pp., Hardcover, $29.95. *press.princeton.edu*



From teleportation and space elevators to alien contact and interstellar travel, science fiction and fantasy writers have come up with some brilliant and innovative ideas. Yet how plausible are these ideas? Which concepts might actually happen, and which ones wouldn't work at all? *Wizards, Aliens, and Starships* delves into the most extraordinary details in science fiction and fantasy — such as time warps, shape changing, rocket launches, and illumination by floating candle — and shows readers the physics and math behind the phenomena. With simple mathematical models, and in most cases using no more than high-school algebra, Adler ranges across a plethora

of remarkable imaginings, from the works of Ursula K. Le Guin to *Star Trek* and *Avatar*, to explore what might become reality. This book will speak to anyone wanting to know about the correct — and incorrect — science of science fiction and fantasy.

H. G. Wells' The First Men in the Moon: The Story of the 1919 Film.
By Robert Godwin. Griffin Media, 2013. Paperback and mini-DVD, 50 pp., $9.95.
www.apogeeprime.com

In 1919 the Gaumont Motion Picture Studio created the first movie to ever be based entirely on a famous science fiction novel. That movie was an adaptation of H. G. Wells' *The First Men in the Moon*. Wells himself was on hand to oversee the costumes and sets. A lost treasure of the silent era of film, the movie is now believed to be lost forever. In 2010 The British Film Institute named it one of the 75 "most desirable" missing films. In 2013, Godwin uncovered a series of artifacts from the film's original release, including a complete synopsis of the plot that was different from Wells' book, newspaper reviews, and most importantly, a series of still images from the production. His research produced enough material to make this fascinating mini-history of the world's first "true" science fiction film. This pocketbook includes a mini-DVD recreation of the 1919 production of *The First Men in the Moon*.

DVD

Alien Planets Revealed.
Produced by PBS, 2013, one disc. $24.99. *www.shoppbs.org*

It's a golden age for planet hunters: Recently, they've discovered more than 750 planets orbiting stars beyond our Sun. Some of them, like a planet called Kepler-22b, might even be able to harbor life. What would that life look like? Combining startling animation with input from expert astrobiologists, *Alien Planets Revealed* takes viewers on a journey of the imagination as we "build" aliens from the ground up.

GLOBES

Mercury Globe.
Produced by Sky Publishing, 2014. $99.95. *www.shopatsky.com*

For centuries, our solar system's innermost planet was shrouded in mystery. Now, for the first time ever, you can use a globe to explore Mercury's entire surface! This new *Sky & Telescope* 12-inch globe was made possible by NASA's MESSENGER spacecraft, which recently finished imaging the entire planet. The base map comes from about 18,000 MESSENGER images, and special image processing has preserved the natural light and dark shading of the surface. The names of more than 350 craters and other features are labeled, including craters named after famous artists, musicians, painters, and authors.

FOR KIDS!!!

Mars in My Room Light Up Planet.

Produced by Uncle Milton. $36.99. *unclemiltonstore.com*

Watch the mysterious Red Planet light up and come to life on your wall! See pinpoints of light that show where Mars rovers have landed. Then, place different lander/rover stickers to mark their landing locations. Authentic Mars detail and textured surface! This kit includes Mars Rover/Lander Mission cards and stickers, remote control, and instructions, and requires four AA and two AAA batteries (not included). For ages 6 and up.

LEGO NASA Mars Science Laboratory Curiosity Rover.

Produced by LEGO. $29.99. *shop.lego.com*

Designed by real Curiosity Rover engineer Stephen Pakbaz, this amazing LEGO version of the highly advanced mobile laboratory features lots of great details, such as six-wheel rocker-bogie suspension, articulated robotic arm, and multiple camera sets. This 295-piece model kit also comes with a fascinating booklet with building instructions and information about the history of Mars exploration and the Curiosity Rover, plus a display plate complete with LEGO brick martian rocks — perfect for testing out the rover's go-anywhere suspension. For ages 10 and up.

Rock On! Geology Game and Rock Collection.

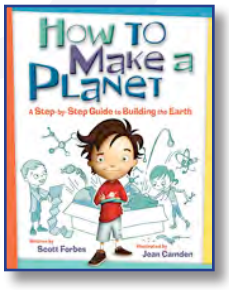
Produced by ilaughnlearn. $25.00. Available from *amazon.com*

Spark an interest in rocks and geology with this geology game and rock collection. This American-made set consists of an 18-piece rock collection, playing cards for up to six players, rock call cards, a master rock guide, playing pieces, and instructions all contained in a carrying case. For ages 5 and up.

Could We Live on Other Planets?

By Michael Portman. Gareth Stevens Publishing, 2014, 32 pp., Hardcover, $25.25. *www.garethstevens.com*

The Kepler space telescope searches for planets outside our solar system. So far, it has found hundreds. Scientists have tried to find out whether any of these planets could be habitable, a possible second home for us. Readers of this fascinating topic will find out what we would need to live on another planet and learn the latest theories about creating another Earth-like world. Imaginative images will help readers picture themselves as one of the first settlers of a new home planet. For grades 2–3.



How to Make a Planet: A Step-by-Step Guide to Building the Earth.

By Scott Forbes. Kids Can Press, 2014, 64 pp., Hardcover, $17.95. *www.kidscanpress.com*

Offering a new spin on astronomy and Earth sciences books for kids, this out-of-this-world how-to guide details the making of a planet, namely the incredible, life-sustaining, one-in-a-billion planet Earth, starting with its basic ingredients, protons and neutrons, and making abstract concepts easier to understand. For ages 8–12.

Calendar 2014

March

1–8	**IEEE Aerospace Conference,** Big Sky, Montana. *http://www.aeroconf.org/*
4–5	**SELENE Symposium 2014: International Symposium of Lunar Science and Exploration Using Data from Multi-Instruments,** Tokyo, Japan. *http://www.isas.jaxa.jp/j/researchers/symp/2014/0304_selene_en.shtml*
16	**SHARAD/MARSIS Data Users' Workshop,** The Woodlands, Texas. *http://www.ig.utexas.edu/sharad_marsis/*
16	**International Workshop on Scientific Opportunities in Cislunar Space (SOCS),** Houston, Texas. *http://www.socsworkshops.com/*
17–20	**Science with the Hubble Space Telescope IV: Looking to the Future,** Rome, Italy. *http://www.stsci.edu/institute/conference/hst4*
17–21	**45th Lunar and Planetary Science Conference,** The Woodlands, Texas. *http://www.hou.usra.edu/meetings/lpsc2014*
17–21	**Search for Life Beyond the Solar System — Exoplanets, Biomarkers and Instruments,** Tucson, Arizona. *http://www.ebi2014.org*
18–21	**International Workshop on Scientific Use, Digitization and Preserving Astronomical Photographic Records,** Prague, Czech Republic. *http://www.astroplate.cz/*
20–22	**Meeting of the Astronomical Society of India 2014,** Mohali, India. *http://www.asi2014.in/*
26–28	**First ExoMars 2018 Landing Site Selection Workshop,** Madrid, Spain. *http://www.sciops.esa.int/index.php?project=CONF2014&page=EXOMARS-LSS*

April

1–3	**International Cometary Workshop,** Toulouse, France. *http://icw.space.swri.edu*
8–10	**Titan Through Time Workshop 3,** Laurel, Maryland. *https://dnnpro.outer.jhuapl.edu/titanthroughtime3/Home.aspx*
8–11	**4th International Workshop on Lunar and Planetary Compact and Cryogenic Science and Technology Applications (LSA 4),** Cocoa Beach, Florida. *http://lsaworkshops.com/*
22–24	**Humans to Mars Summit,** Washington, DC. *http://spaceref.com/calendar/calendar.html?pid=8221*
27–May 2	**European Geosciences Union General Assembly,** Vienna, Austria. *http://www.egu2014.eu/*
28–29	**Interplanetary Small Satellite Conference,** Pasadena, California. *http://www.intersmallsatconference.org*
28–May 1	**45th Annual Meeting of the American Astronomical Society's Division on Dynamical Astronomy (DDA 2014),** Philadelphia, Pennsylvania. *http://dda.aas.org/meetings/2014/index.html*
28–May 1	**Habitable Worlds Across Time and Space,** Baltimore, Maryland. *http://www.stsci.edu/institute/conference/habitable-worlds*
28–May 3	**21st Young Scientists' Conference on Astronomy and Space Physics,** Kiev, Ukraine. *http://ysc.kiev.ua/*

May

5–9	**13th International Conference on Space Operations (SpaceOps 2014),** Pasadena, California. *http://geocalendar.agu.org/meeting/spaceops-2014-13th-international-conference-on-space-operations/*
13	**EnVision: M4 Venus Orbiter Workshop,** London, England. *http://www.lpi.usra.edu/planetary_news/wp-content/uploads/2014/02/M4-Venus-Workshop.pdf*
13–14	**Mars Exploration Analysis Group (MEPAG) Meeting,** Washington, DC. *http://mepag.jpl.nasa.gov/*
13–15	**The Formation of the Solar System Conference,** Bonn, Germany. *https://indico.mpifr-bonn.mpg.de/theFormationOfTheSolarSystem*
14–16	**First Landing Site Workshop for the 2020 Mars Rover Mission,** Washington, DC. *http://marsnext.jpl.nasa.gov*
17–21	**51st Annual Meeting of the Clay Minerals Society,** College Station, Texas. *https://cms2014.tamu.edu/*

19–21 **Venus Exploration Targets Workshop,** Houston, Texas. *http://www.hou.usra.edu/meetings/venus2014/*

20–22 **Biosignatures Across Space and Time,** Bergen, Norway. *http://www.nordicastrobiology.net/Biosignatures2014/*

26–31 **Accretion and Early Differentiation of the Earth and Terrestrial Planets (ACCRETE),** Nice, France. *http://www.accrete.uni-bayreuth.de/?page=workshops*

27–28 **3rd Interplanetary CubeSat Workshop (iCubeSat 2014),** Pasadena, California. *http://icubesat.org/*

28–30 **Workshop on Planetary Volcanism,** Houston, Texas. *http://www.hou.usra.edu/meetings/volcanism2014*

June

1–5 **Second Annual Meeting of the AAS Laboratory Astrophysics Division (LAD 2014),** Boston, Massachusetts. *http://aas.org/aas-224th-meeting/224th-meeting-laboratory-astrophysics-division-sessions*

8–14 **Goldschmidt 2014,** Sacramento, California. *http://goldschmidt.info/2014/index*

9–12 **Fifth Meeting of the Space Resources Roundtable and the Planetary and Terrestrial Mining Sciences Symposium,** Golden, Colorado. *http://www.isruinfo.com//docs/srr_ann/srr_xv_ptmss_first_announcement.pdf*

10–14 **International Venus Workshop,** Catania, Sicily, Italy. *http://www.iaps.inaf.it/Venus2013/*

15–19 **11th International GeoRaman Conference,** St. Louis, Missouri. *http://georaman2014.wustl.edu/*

16–20 **11th International Planetary Probe Workshop,** Pasadena, California. *http://www.hou.usra.edu/meetings/ippw2014/*

16–20 **48th ESLAB Symposium: New Insights into Volcanism Across the Solar System,** Noordwijk, The Netherlands. *http://congrexprojects.com/2014-events/48-ESLAB/introduction*

24–27 **6th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS),** Lausanne, Switzerland. *http://core.ieee-whispers.com/*

30–Jul 4 **Asteroids, Comets, Meteors (ACM),** Helsinki, Finland. *http://www.helsinki.fi/acm2014/*

30–Jul 8 **ISIMA 2014: Gravitational Dynamics,** Toronto, Canada. *http://isima.ucsc.edu/current.html*

July

4–11 **6th International Summer School on Radar/SAR Systems,** Bonn, Germany. *http://www.radarsummerschool.fraunhofer.de*

6–11 **CoRoT3-KASC7: The Space Photometry Revolution,** Toulouse, France. *http://kasc7.asteroseismology.org*

6–11 **Origins 2014,** Nara, Japan. *http://www.origin-life.gr.jp/origins2014/index.html*

7–11 **Nuclei in the Cosmos,** Debrecen, Hungary. *http://www.nic2014.org/*

7–11 **Complex Planetary Systems,** Namur, Belgium. *http://www.cps-iau.be*

7–11 **6th Alfven Conference: Plasma Interactions with Solar System Objects, Anticipating Rosetta, MAVEN, and Mars Orbiter Mission,** London, United Kingdom. *https://www.ucl.ac.uk/mssl/planetary-science/alfven-conference*

9–11 **The Universe in the Light of Akari and Synergy with Future Large Space Telescopes,** Oxford, United Kingdom. *http://akari.open.ac.uk/*

14–18 **Eighth International Mars Conference,** Pasadena, California. *http://www.hou.usra.edu/meetings/8thmars2014/*

21–23 **NASA Exploration Science Forum (ESF),** Moffett Field, California. *http://sservi.nasa.gov/NESF2014/*

21–25 **2014 Sagan Exoplanet Summer Workshop: Imaging Planets and Disks,** Pasadena, California. *http://nexsci.caltech.edu/workshop/2014/index.shtml*

21–25 **Eighth International Conference on Aeolian Research (ICAR VIII),** Lanzhou, China. *http://www.2014icar8.com/AboutUs/16.html*

28–30 **Workshop on the Study of the Ice Giant Planets,** Laurel, Maryland. *http://www.hou.usra.edu/meetings/icegiants2014/*

28–Aug 1 **11th Annual Meeting of the Asia Oceania Geosciences Society,** Sapporo, Japan. *http://www.asiaoceania.org/aogs2014/public.asp?page=home.htm*

28–Aug 1 **Characterizing Planetary Systems Across the HR Diagram,** Cambridge, England. *http://www.ast.cam.ac.uk/meetings/2013/AcrossHR*

29–31 **Small Bodies Assessment Group 11th Meeting,** Washington, DC. *http://www.lpi.usra.edu/sbag/*

August

2–10	**40th COSPAR Scientific Assembly,** Moscow, Russia. *http://www.cospar-assembly.org/*
4–8	**Saturn in the 21st Century,** Madison, Wisconsin. *http://www.ssec.wisc.edu/meetings/21st_saturn/*
4–8	**Cosmic Dust VII,** Osaka, Japan. *https://www.cps-jp.org/~dust/*
6–8	**5th Planetary Crater Consortium Meeting,** Flagstaff, Arizona. *http://www.planetarycraterconsortium.nau.edu*

September

7	**Workshop on Using Radar Imagery for Meteorite Fall Detection and Recovery,** Casablanca, Morocco. *http://www.metsoc2014casablanca.org/workshops.php*
7–12	**European Planetary Science Congress (EPSC 2014),** Cascais, Portugal. *http://www.epsc2014.eu*
8–10	**Planet Formation and Evolution 2014,** Kiel, Germany. *http://www1.astrophysik.uni-kiel.de/~kiel2014/main/*
8–11	**Electrification in Dusty Atmospheres Inside and Outside the Solar System,** Pitlochry, United Kingdom. *http://leap1.sciencesconf.org/*
8–12	**Living Together: Planets, Stellar Binaries and Stars with Planets,** Litomysl, Czech Republic. *http://astro.physics.muni.cz/kopal2014/*
8–13	**77th Annual Meeting of the Meteoritical Society,** Casablanca, Morocco. *http://www.metsoc2014casablanca.org/*
10–12	**Planet Formation and Evolution 2014,** Kiel, Germany. *http://www1.astrophysik.uni-kiel.de/~kiel2014/main/*
15–19	**Towards Other Earths II. The Star-Planet Connection,** Porto, Portugal. *http://www.astro.up.pt/toe2014*
23–27	**National Conference of Astronomers of Serbia,** Belgrade, Serbia. *http://poincare.matf.bg.ac.rs/~astroweb/nkas17/*
29–Oct 3	**65th International Astronautical Congress,** Toronto, Canada. *http://www.iafastro.com/index.php/events/iac/iac-2014*

October

13–16	**The 14th European Astrobiology Conference (EANA 2014),** Edinburgh, Scotland. *http://www.astrobiology.ac.uk/eana2014/*
19–22	**GSA Annual Meeting,** Vancouver, British Columbia, Canada. *http://www.geosociety.org/meetings/2014/*
23–26	**Solar Eclipse Conference 2014,** Alamagordo, New Mexico. *http://www.eclipse-chasers.com/SEC2014.html*
27–31	**Réunion des Sciences de la Terre,** Pau, France. *http://rst2014-pau.sciencesconf.org/?lang=en*

November

4–7	**International Workshop on Instrumentation for Planetary Missions,** Washington, DC. *http://ssed.gsfc.nasa.gov/IPM/*
9–14	**46th Meeting of the American Astronomical Society Division for Planetary Sciences (DPS 2014),** Tucson, Arizona. *http://dps.aas.org/meetings*
16–21	**Triple Evolution and Dynamics in Stellar and Planetary Systems,** Haifa, Israel. *http://trendy-triple.weebly.com/*

December

15–19	**AGU Fall Meeting,** San Francisco, California. *http://geocalendar.agu.org/meeting/2014-agu-fall-meeting/*