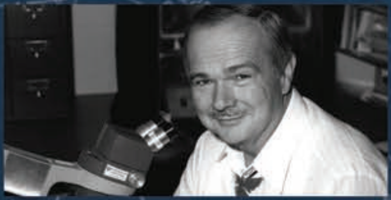
USGS ASTROGEOLOGY SCIENCE CENTER

50 YEARS OF SURVEYING THE SOLAR SYSTEM

USGS 50 YEARS

ASTROGEOLOGY SCIENCE CENTER
1963 - 2013



Lunar and Planetary Information

BULLETIN

Universities Space Research Association — Lunar and Planetary Institute

CONTENTS

December 2013
Issue 135

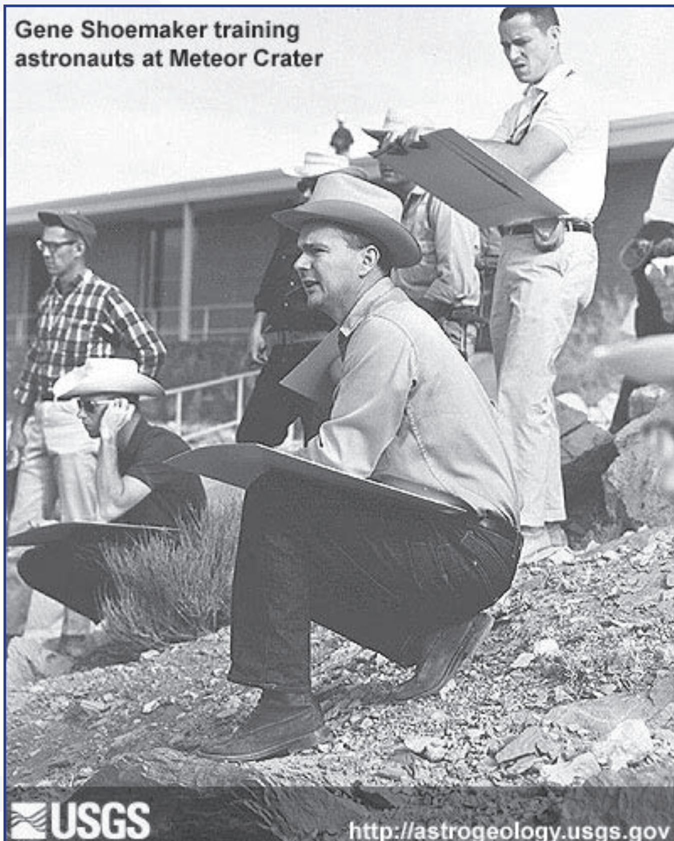
www.lpi.usra.edu/lpib

USGS Astrogeology Science Center

50 Years of Surveying the Solar System

— Laszlo Kestay, USGS Astrogeology Science Center

Note from the Editors: This issue's lead article is the first in a series of reports describing the history and current activities of NASA's planetary research facilities located nationwide. We begin this series with a report on the USGS Astrogeology Science Center in Flagstaff, Arizona, where lunar astronauts were trained and the planets are mapped, and which is celebrating its 50th anniversary this year. Enjoy!
— Paul Schenk and Renée Dotson

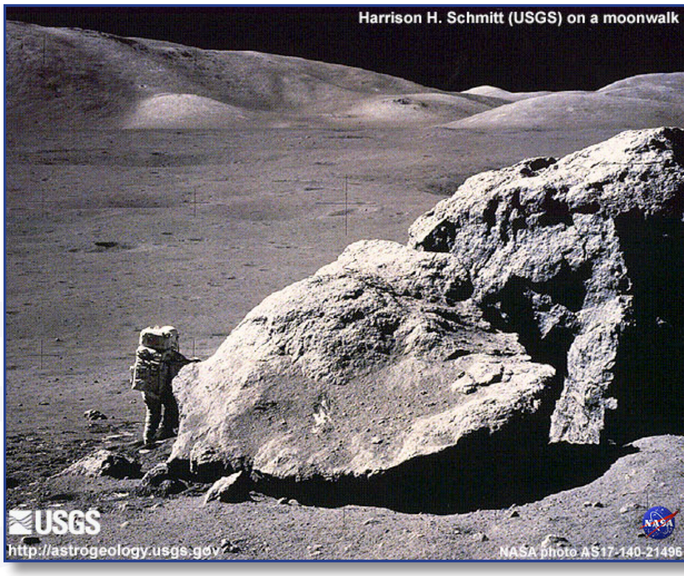


Photograph of Gene Shoemaker instructing Apollo astronauts in the formation of impact craters and field geology techniques at Barringer (Meteor) Crater.

This year marks the 50th anniversary of the U.S. Geological Survey (USGS) Astrogeology Science Center in Flagstaff, Arizona. The primary aim of "Astrogeology" has consistently been to support the U.S. space program with the scientific and cartographic expertise of the USGS. Through this center, the USGS has been involved in every human and nearly every robotic mission to an extraterrestrial solid surface in our solar system.

On September 18, 1961, Eugene "Gene" Shoemaker persuaded the USGS to set up the "Astrogeologic Studies Unit" in Menlo Park, California. While the field would later be known as "planetary science," Shoemaker's intention was to focus on the geology to be done by astronauts on the Moon and elsewhere. In 1963, the "unit" was upgraded to a "Branch" and moved to Flagstaff, Arizona, to be closer to superb analogs for extraterrestrial studies such as the Grand Canyon, San Francisco Volcanic Field, and Barringer (Meteor) Crater.

The early years of Astrogeology were focused on preparing for and supporting the NASA Apollo program, which had the objective of taking humans to the Moon and returning them safely before 1970. Shoemaker was instrumental in making geology a major emphasis for the Apollo missions, and the USGS was at the heart of training the astronauts. The task grew so large that between 1967 and 1973 the group was temporarily divided into two: one retaining the moniker of "Astrogeology" and the other dubbed the "Branch of Surface Planetary Exploration." The only scientist to step on the Moon, Harrison "Jack" Schmitt, was at one time a USGS Astrogeology employee.

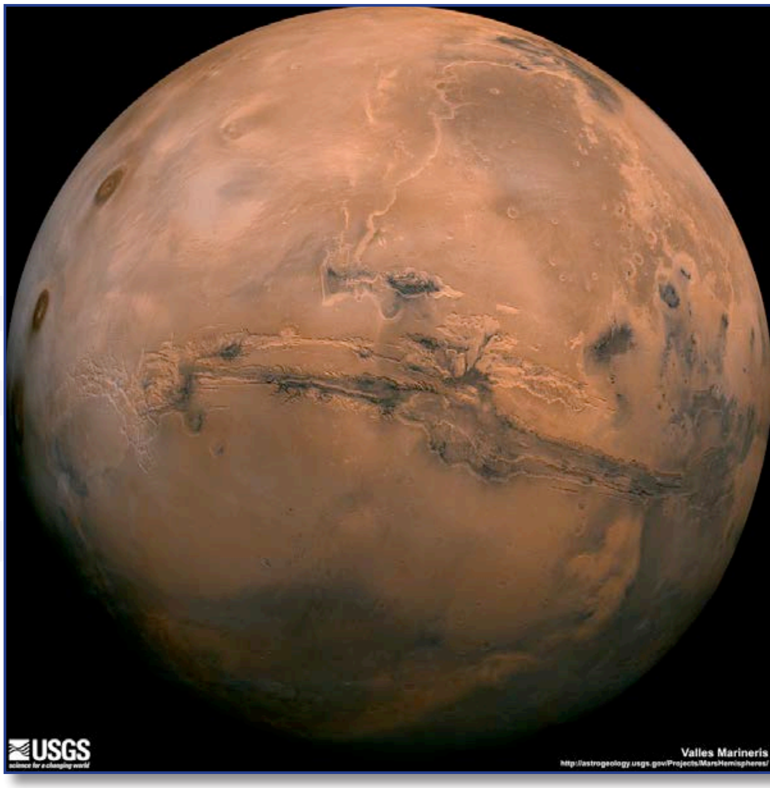


Photograph of Jack Schmitt on the surface of the Moon during the Apollo 17 mission. Schmitt worked for USGS Astrogeology before becoming the only geologist to go to the Moon.

Some of the highlights from this period included testing a variety of devices astronauts might use on the Moon, such as a Sun compass, geologic hammer, soil scoops, television cameras, color calibration targets, vehicles from one-person rovers to multiperson mobile laboratories, and even jet packs. While some of these devices never reached the Moon, a notable success was proving the necessity of real-time video and the utility of a rover. In addition to testing tools and concepts for Apollo surface operations, Astrogeology played a leading role in the training of the actual crews headed to the Moon. This included using many tons of explosives to recreate the crater field of a section of Mare Tranquillitatis in the cinder fields northeast of Flagstaff.

As the Apollo program reached its zenith, it became increasingly clear that the need to train astronauts in field geology was not going to continue. However, the same skills that aided the safe and productive exploration of the Moon by humans were useful for the waves of robotic explorers heading across the solar system. USGS scientists and cartographers were key members of the Mariner, Viking, Voyager, and Galileo mission teams. The combination of capabilities inherent to USGS meant that these team members not only focused on pioneering scientific discoveries, but also on organizing the information into the form of maps and preserving the data as a legacy for later generations. This type of work carried on through the drought of new planetary missions in the 1980s and few successes in the early 1990s. For example, the Mars Digital Image Mosaics were produced from thousands of Viking Orbiter images precisely positioned via nearly 40,000 control points through much of the 1980s and 1990s. This era moved planetary cartography from film and airbrush experts to computer software manipulating pixels and virtual benchmarks.

2008 photo of the staff of the USGS Astrogeology Science Center.



This enhanced mosaic of the Valles Marineris hemisphere of Mars is just one example of the stunning planetary imagery produced and distributed by the USGS Astrogeology Science Center. The image is projected into point perspective, a view similar to that which one would see from a spacecraft. The distance is 2500 kilometers from the surface of the planet, with the scale being 0.6 kilometers/pixel. The mosaic is composed of 102 Viking Orbiter images of Mars.

Currently, the USGS Astrogeology Science Center supports a flotilla of U.S. and international robotic explorers across the solar system. These span from the NASA MESSENGER mission in orbit around Mercury to the New Horizons spacecraft headed for Pluto. In between, Astrogeology supports missions in orbit around the Moon; rovers and orbiters investigating Mars; U.S. and international missions exploring the asteroid belt; and the NASA-ESA Cassini-Huygens mission to Saturn and its giant moon, Titan.

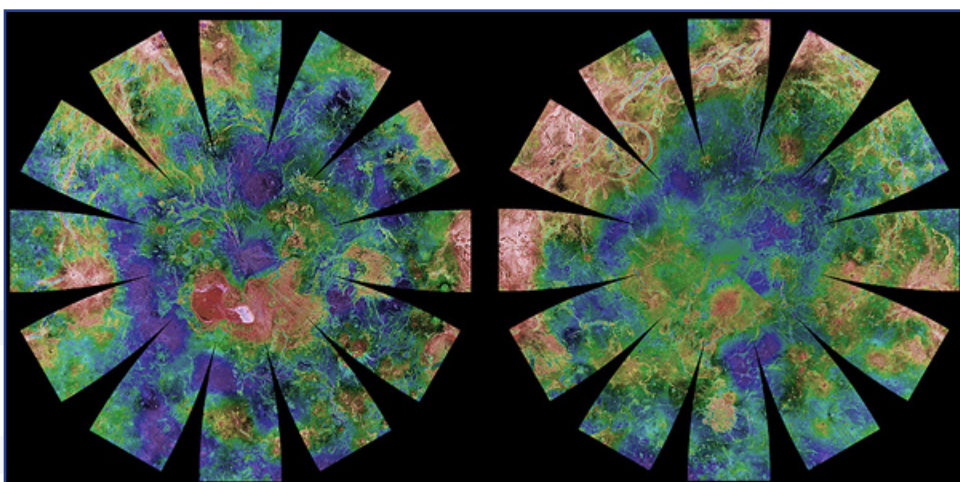
Astrogeology staff support these missions with scientific expertise, operations of the spacecraft, cartography, and providing ready access to the acquired information. As an integral part of the larger planetary science community, Astrogeology scientists provide input to NASA on where future planetary missions should go and the kinds of instruments these missions should carry. Astrogeology staff play a direct role in the operation of the HiRISE camera on the Mars Reconnaissance Orbiter, the Mars Exploration Rover Opportunity, and the Mars Science Laboratory Curiosity rover.

An area in which the USGS takes a natural leadership role is in the production of topographic maps of potential landing sites. While there are several groups who can produce excellent topographic maps of the planets, the USGS products are still considered to be the most reliable when a mission's success is on the line. For the Curiosity landing site in Gale crater, the topographic map contained well over a billion elevation measurements, totally eclipsing the data volume of any previous planetary topographic map.

Many instruments and missions rely on the Integrated Software for Imagers and Spectrometers (ISIS) developed by Astrogeology. This is the only freely available software that can precisely map the data collected by NASA spacecraft onto the surface of planetary bodies. To achieve this kind of precision, the images are photogrammetrically "controlled." This means that a host of images of the same location are analyzed to simultaneously solve for (1) the position of features on the surface, (2) topography, (3) the position and orientation of the spacecraft, and (4) the optical path within the instrument. Controlling the volumes of data now available from Mars and the Moon is extremely time consuming in terms of both computing and human operator time and is therefore not usually done by missions as a regular part of their processing stream. However, such precision cartography is a prerequisite for correctly combining (or fusing) disparate datasets of a region.

The synthesis of different types of data into an understanding of planetary geology is best exemplified by the production of geologic maps. The USGS Astrogeology Science Center leads the NASA Planetary Geologic Mapping Program. This involves developing the mapping standards, establishing templates for digital mapping, and carrying all maps through the USGS review and publication process. Astrogeology also plays a key role in archiving past data and making raw and derived products readily available to the international planetary science community as well as the general public. Astrogeology has about 1 Petabyte of digital storage and a variety of web services to facilitate this. Two large compute clusters process the data into more scientifically useful products.

The funding for Astrogeology comes almost exclusively from NASA, with every dollar won via some type of competitive selection process. None of the awards are for more than four years, requiring frequent justification to NASA as to why USGS should be doing these activities. This has the virtues of assuring that Astrogeology is rapidly responsive to NASA's evolving needs and that it is providing the best value to the government. With the repeated and dramatic changes to the U.S. space program over the years, it is a major accomplishment that Astrogeology has become a fixture of humankind's exploration of the heavens.



Among other products made available by the USGS Astrogeology Science Center are images that users can download and print to create their own planetary globes. The above photomosaics feature Venus Magellan images, and the number, size, and placement of text annotations were chosen to provide a general orientation of prominent features on a 12-inch globe. Features are labeled with names approved by the International Astronomical Union. A specialized program was used to create the "flower petal" appearance of the photomosaic; the area of each petal from 0° to 75° latitude is in the Transverse Mercator projection, and the area from 75° to 90° latitude is in the Lambert Azimuthal Equal-Area projection. The northern hemisphere is shown on the left and the southern hemisphere is shown on the right.

About the Cover:

Top right: Eugene "Gene" Shoemaker, the founder of the USGS Astrogeology Science Center.
Middle right: The lobby of the Shoemaker Building.
Bottom: Exterior shot of the Shoemaker Building at the USGS Astrogeology Science Center.

All images on the cover and within this article are courtesy of USGS.

About the Author:

Dr. Laszlo Kestay (formerly Keszthelyi) is the Director of the USGS Astrogeology Science Center. He received his Ph.D. in geology in 1994 from the California Institute of Technology under advisor Bruce Murray and the tutelage of the USGS Hawaiian Volcanoes Observatory, researching the cooling of lava flows. Prior to joining the Astrogeology Program at USGS in 2003, he worked with Alfred McEwen at the University of Arizona on the Galileo SSI and Mars Reconnaissance Orbiter HiRISE instruments.

China Launches Probe and Rover to Moon

China launched the Chang'e-3 lunar probe with the country's first Moon rover onboard early on December 2, marking a significant step toward deep space exploration. The probe's carrier, an enhanced Long March-3B rocket, blasted off from the Xichang Satellite Launch Center in southwest China at 1:30 a.m. local time. Chang'e-3 is expected to land on the Moon in mid-December to become China's first spacecraft to soft land on the surface of an extraterrestrial body. It is also the first Moon lander launched in the twenty-first century. The probe entered the Earth-Moon transfer orbit as scheduled, with a perigee of 200 kilometers and apogee of 380,000 kilometers. "The probe has already entered the designated orbit," said Zhang Zhenzhong, director of the launch center in Xichang. "I now announce the launch was successful."

The Long March-3B carrier rocket carrying China's Chang'e-3 lunar probe blasted off from the launch pad at Xichang Satellite Launch Center, southwest China's Sichuan Province, on December 2, 2013. It will be the first time for China to send a spacecraft to soft land on the surface of an extraterrestrial body, where it will conduct surveys on the Moon. Credit: Xinhua/ Li Gang.

Amid efforts to promote the lunar probe campaign among the public, the Chinese Academy of Sciences opened a microblog account for the Chang'e-3 mission, attracting more than 260,000 fans who continuously posted congratulatory comments. The probe's soft-landing is the most difficult task during the mission, said Wu Weiren, the lunar program's chief designer. "This will be a breakthrough for China to realize zero-distance observation and survey on the Moon." Weiren added that more than 80% of the technologies and products used by the mission are newly developed.

Chang'e-3 will lay a solid foundation for manned lunar orbit missions and lunar landings. China has not revealed the roadmap for its manned mission to land on the Moon. The United States and the former Soviet Union are the only countries to have previously successfully soft landed on the Moon. Chang'e-3, comprising a lander and a Moon rover called "Yutu" (Jade Rabbit), presents a modern scientific version of an ancient Chinese myth that a lady called Chang'e, after swallowing magic pills, took her pet "Yutu" to fly toward the Moon, where she became a goddess, and has been living there with the white rabbit ever since.

Scheduled tasks for the Moon rover include surveying the Moon's geological structure and surface substances, while looking for natural resources. A telescope will be set up on the Moon to observe the plasmasphere over Earth and survey the Moon surface using radar. The lunar probe mission is of great scientific and economic significance, said Sun Zezhou, chief designer of the lunar probe. The mission has contributed to the development of a number of space technologies and some of them can be applied in civilian sector, he said.

Chang'e-3 is part of the second phase of China's lunar program, which includes orbiting, landing, and returning to Earth. It follows the success of the Chang'e-1 and Chang'e-2 missions in 2007 and 2010. After orbiting for 494 days and intentionally crashing onto the lunar surface, Chang'e-1 sent back 1.37 terabytes of data, producing China's first complete Moon picture. Launched on October 1, 2010, Chang'e-2 verified some crucial technologies for Chang'e-3 and reconnoitered the landing area. It also made the world's first lunar holographic image with a resolution of 7 meters. Chang'e-2 is currently more than 60 million kilometers away from Earth and has become China's first manmade asteroid. It is heading for deep space and is expected to travel as far as 300 million kilometers from Earth, the longest voyage of any Chinese spacecraft.

China is likely to realize the third step of its lunar program in 2017, which is to land a lunar probe on the Moon, release a Moon rover, and return the probe to Earth. The Moon is considered to be the first step toward exploring a more-distant extraterrestrial body such as Mars. If successful, the Chang'e-3 mission will provide China with the ability to perform *in situ* exploration on an extraterrestrial body, said Sun Huixian, deputy engineer-in-chief in charge of the second phase of China's lunar program. "China's space exploration will not stop at the Moon," he said. "Our target is deep space."

China sent its first astronaut into space in 2003, becoming the third country after Russia and the United States to achieve independent manned space travel. Despite the fast progress of the lunar mission, China is still a relative newcomer in this field. The former Soviet Union first landed its probe on the Moon on January 31, 1966, while the United States first sent humans to the Moon in 1969.

About a day before the launch of Chang'e-3, India's maiden Mars orbiter, named Mangalyaan, left Earth early on Sunday, December 1, for a 300-day journey to the Red Planet. Chinese space scientists are looking forward to cooperation with other countries, including the country's close neighbor India. Li Benzheng, deputy commander-in-chief of China's lunar program, told media earlier that China's space exploration does not aim at competition. "We are open in our lunar program, and cooperation from other countries is welcome," he said. "We hope to explore and use space for more resources to promote human development."

Update: On December 14 at approximately 8:11 a.m. EST (1311 GMT), the Chang'e-3 spacecraft soft-landed on the surface of the Moon. The rover was successfully deployed and is now traversing the lunar surface near the landing site.

LADEE Mission in Commissioning Phase

Artist's concept of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft orbiting the Moon. Credit: NASA Ames/Dana Berry.

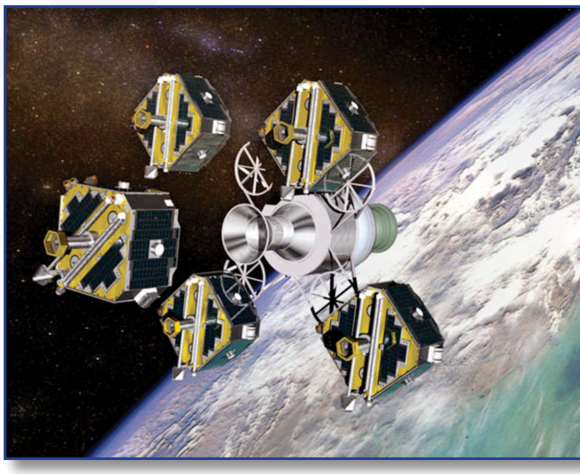
NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft continues to operate in the lunar commissioning orbit at approximately 155 miles (250 kilometers) above the surface of the Moon. The orbit is not perfectly circular because of the Moon's lumpy gravity field. In this orbit, the Mission Operations Team at NASA's Ames Research Center, Moffett Field, California, are testing and calibrating the three science instruments, as well performing the primary Lunar Laser Communication Demonstration (LLCD) experiments. As of November 8, LADEE was at the half-way point in the commissioning, with the first two blocks of science commissioning activities and the first two blocks of LLCD experiments complete.

During the LLCD experiment blocks, the LLCD team demonstrated all-optical acquisition data transfers (without depending on any help from the radio system) at 10 and 20 megabits per second (Mbps) uplink, and transfers at 155, 311, and 622 Mbps downlink. These downlink rates are higher than typical home Internet streaming video. All optical contact attempts with the U.S. ground stations at White Sands in New Mexico and Table Mountain in California have been successful. Later in the experiment, the LLCD team was able to demonstrate the ability to operate through thin clouds, as well as handing off from one ground station to another. This is significant because such a capability will be required for future operational use. The LLCD team also has started contact passes with a European ground station in Tenerife, Spain.

The science instrument commissioning activities also have been going well, with all three instruments taking calibration data. The Neutral Mass Spectrometer (NMS) completed a variety of tests, including its first measurements of atoms and molecules in the lunar atmospheric. The NMS instrument has operated while pointing in many directions to look for atoms and molecules from a variety of sources. The Ultraviolet-Visible Spectrometer (UVS) completed its initial calibrations, including verifying the precise pointing direction of its telescope and solar viewer. The UVS instrument also has peered over the lunar horizon to look for the glow of atoms, molecules and dust in the lunar atmosphere. The Lunar Dust Experiment (LDEX) performed a high-altitude dust survey before dropping to the lower science orbit in November.

The spacecraft has now started the full science phase of the mission. For more information, visit *www.nasa.gov/ladee.*

ARTEMIS Mission Update



Artist's concept of the five THEMIS spacecraft being released from the carrier after launch. Credit: ATK Space Systems/UC Berkeley.

The Acceleration, Reconnection, Turbulence, and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) mission will pursue key questions in both heliophysics and planetary science through observations from a lunar orbit. ARTEMIS redeploys the two outermost satellites of NASA's MIDEX mission THEMIS, which was launched on February 17, 2007, to study the origin of Earth's magnetospheric substorms. ARTEMIS' dual probes capture simultaneous two-point measurements at variable interprobe separations, thus maximizing spatial resolution, facilitating the calibration of measurements, and increasing the volume of data.

The two ARTEMIS spacecraft have now been in elliptical equatorial orbits around the Moon since mid-2011, and continue to operate flawlessly. Both probes are in very stable orbits, and the health of all instruments and the spacecraft remains very good. Current ARTEMIS lunar investigations are focusing on measuring pickup ions from the exosphere, the electrostatic charging of the surface, the plasma wake, and the interaction of the solar wind with remanent crustal magnetic anomalies. ARTEMIS also uses lunar orbit as a platform to observe the solar wind and (around full Moon) the distant terrestrial magnetotail. More details on recent studies can be found at *artemis.ssl.berkeley.edu/publications.shtml*.

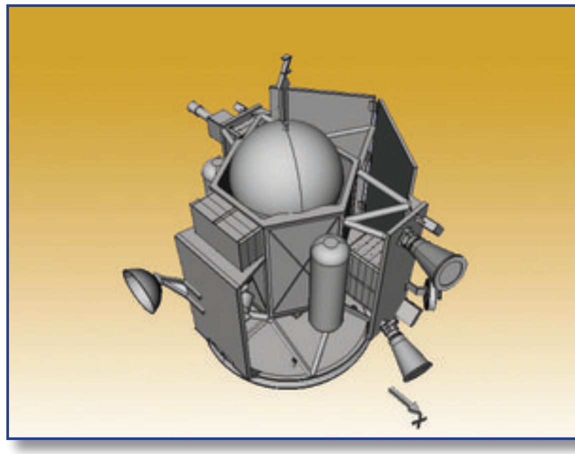
With the LADEE mission now having entered its nominal science orbit, and the Lunar Reconnaissance Orbiter (LRO) placing new emphasis on its own measurements of the lunar exosphere, ARTEMIS plays a key role by providing measurements of the solar and terrestrial plasma that acts as both a source and sink for the lunar exosphere, and that will affect any dust released from the surface. Together, these three missions will team to measure the inputs, dynamics, and outputs of the coupled system formed by the Moon's surface, its dusty exosphere, and the space environment.

All ARTEMIS data is made publicly available on a timescale of a few days, and the ARTEMIS team welcomes participation from the community. More information on the mission, instrumentation, data (including summary plots), software, etc., is available at *artemis.ssl.berkeley.edu*.

ESA Concludes Student ESMO Moon Orbiter Project

Although the European Space Agency's (ESA) European Student Moon Orbiter (ESMO) project passed its preliminary design review (PDR) last year, the review board announced that the project would not continue to the next phase. While confident that the mission's objectives could be met, following a full evaluation of the costs of completing the program, ESA education officials decided that ESMO was not sustainable within current budget constraints.

ESMO was started as an inspirational educational project that would attract science and engineering students with a long-term objective of ensuring a bright future for Europe's space industry. It also offered a unique opportunity for students to contribute to the scientific knowledge and future exploration of the Moon by returning new data and testing new technologies.



Internal view of the European Student Moon Orbiter. Credit: ESA.

These objectives were spectacularly successful, with more than 300 students from over 20 different universities from across Europe contributing to the project to date. The students performed their work on ESMO as part of their academic studies, under the supervision of their university staff, with Surrey Satellite Technology Ltd. (SSTL), the ESMO industrial prime contractor, in charge of project management and technical development. The educational objectives of the project have been achieved by providing students with technical guidance and mentoring from senior SSTL and ESA experts, through project workshops, intensive internships, and concurrent engineering sessions.

The PDR was conducted by a panel of ESA technical experts from the Directorates of Technical and Quality Management, and Human Spaceflight and Operations. They concluded that the information presented was sufficient to demonstrate that the mission objectives could be met: using an onboard propulsion system to reach lunar orbit after a low-cost piggyback launch into Earth orbit, followed by imaging of the lunar surface and other experiments. After the PDR, the Education Office conducted a thorough evaluation of the total cost-to-completion of the project, based on the approved preliminary design.

"Unfortunately, the total cost has increased during the evolution of the project to a level which substantially exceeds the current and projected budget constraints of the Education Office," said Hugo Marée, Head of ESA's Education and Knowledge Management Office. However, the PDR confirmed that the approved preliminary design of ESMO is a valid, low-cost option for reaching lunar orbit or interplanetary space with a small payload. This capability could be exploited by ESA in the development of future missions beyond low-Earth orbit.

The United Launch Alliance Atlas V rocket with NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft launched from the Cape Canaveral Air Force Station Space Launch Complex 41 on November 18. Credit: NASA/Bill Ingalls.

NASA Launches MAVEN to Study Upper Atmosphere of Mars

A NASA mission that will investigate how Mars lost its atmosphere and abundant liquid water launched into space on November 18 from Cape Canaveral Air Force Station in Florida. The agency's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft separated from an Atlas V Centaur rocket's second stage 53 minutes after launch. The solar arrays deployed approximately one hour after launch and currently power the spacecraft. MAVEN now is embarking on a 10-month interplanetary cruise before arriving at Mars next September.

"MAVEN joins our orbiters and rovers already at Mars to explore yet another facet of the Red Planet and prepare for human missions there by the 2030s," NASA Administrator Charles Bolden said. "This mission is part of an integrated and strategic exploration program that is uncovering the mysteries of the solar system and enabling us to reach farther destinations."

MAVEN will spend the first four weeks following launch powering on and checking out each of its eight instruments. Upon arrival at Mars in September, the spacecraft will execute an orbit insertion maneuver, firing six thrusters that will allow it to be captured into Mars' orbit. In the following five weeks, MAVEN will establish itself in an orbit where it can conduct science operations, deploy science appendages, and commission all instruments before starting its one-Earth-year scientific primary mission.

"After 10 years of developing the mission concept and then the hardware, it's incredibly exciting to see MAVEN on its way," said Bruce Jakosky, principal investigator at the University of Colorado's Laboratory for Atmospheric and Space Physics (CU/LASP) in Boulder, Colorado. "But the real excitement will come in 10 months, when we go into orbit around Mars and can start getting the science results we planned."

MAVEN is traveling to Mars to explore how the Red Planet may have lost its atmosphere over billions of years. By analyzing the planet's upper atmosphere and measuring current rates of atmospheric loss, MAVEN scientists hope to understand how Mars transitioned from a warm, wet planet to the dry desert world we see today. For more information, visit *lasp.colorado.edu/home/maven*.

NASA Rover Confirms Mars Origin of Some Meteorites

Examination of the martian atmosphere by NASA's Curiosity Mars rover confirms that some meteorites that have dropped to Earth really are from the Red Planet. A key new measurement of the inert gas argon in Mars' atmosphere by Curiosity's laboratory provides the most definitive evidence yet of the origin of Mars meteorites while at the same time providing a way to rule out martian origin of other meteorites.

The new measurement is a high-precision count of two forms of argon — argon-36 and argon-38 — accomplished by the Sample Analysis at Mars (SAM) instrument inside the rover. These lighter and heavier forms, or isotopes, of argon exist naturally throughout the solar system. On Mars the ratio of light to heavy argon is skewed because much of that planet's original atmosphere was lost to space. The lighter form of argon was taken away more readily because it rises to the top of the atmosphere more easily and requires less energy to escape. That left the martian atmosphere relatively enriched in the heavier isotope, argon-38.

This rectangular version of a self-portrait of NASA's Mars rover Curiosity combines dozens of exposures taken by the rover's Mars Hand Lens Imager (MAHLI) during the 177th martian day, or sol, of Curiosity's work on Mars. The rover is positioned at a patch of flat outcrop called "John Klein," which was selected as the site for the first rock-drilling activities by Curiosity. The self-portrait was acquired to document the drilling site. Credit: NASA/JPL-Caltech/MSSS.

Years of past analyses by Earth-bound scientists of gas bubbles trapped inside martian meteorites had already narrowed the martian argon ratio to between 3.6 and 4.5 (i.e., 3.6 to 4.5 atoms of argon-36 to every one of argon-38). Measurements by NASA's Viking landers in the 1970s put the martian atmospheric ratio in the range of four to seven. The new SAM direct measurement on Mars now pins down the correct argon ratio at 4.2.

"We really nailed it," said Sushil Atreya of the University of Michigan, Ann Arbor, lead author of an October 16 paper reporting the finding in *Geophysical Research Letters*. "This direct reading from Mars settles the case with all martian meteorites."

One reason scientists have been so interested in the argon ratio in martian meteorites is that it was — before Curiosity — the best measure of how much atmosphere Mars has lost since the planet's wetter, warmer days billions of years ago. Figuring out the planet's atmospheric loss would enable scientists to better understand how Mars transformed from a once water-rich planet, more like our own, into today's drier, colder and less-hospitable world.

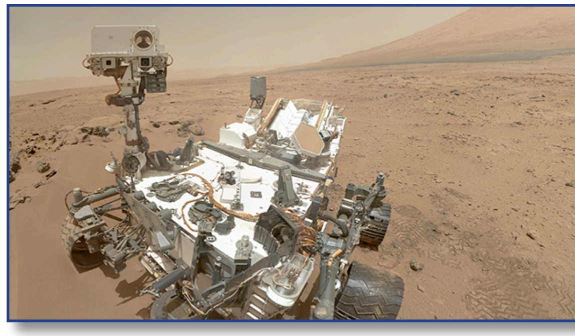
Had Mars held onto all of its atmosphere and its original argon, its ratio of the gas would be the same as that of the Sun and Jupiter. Those bodies have so much gravity that isotopes can't preferentially escape, so their argon ratio — which is 5.5 — represents that of the primordial solar system. While argon makes up only a tiny fraction of the gas lost to space from Mars, it is special because it's a noble gas. That means the gas is inert, not reacting with other elements or compounds, and therefore a more straightforward tracer of the history of the martian atmosphere.

"Other isotopes measured by SAM on Curiosity also support the loss of atmosphere, but none so directly as argon," said Atreya. "Argon is the clearest signature of atmospheric loss because it's chemically inert and does not interact or exchange with the martian surface or the interior. This was a key measurement that we wanted to carry out on SAM."

The Curiosity measurements do not directly measure the current rate of atmospheric escape, but NASA's next mission to Mars, the Mars Atmosphere and Volatile Evolution Mission (MAVEN), is designed to do so. For more information about Curiosity, visit *www.nasa.gov/msl* or *mars.jpl.nasa.gov/msl*. For more information about the SAM instrument, visit *ssed.gsfc.nasa.gov/sam/index.html*.

First Mars Science Results from Curiosity Rover Published

NASA's Curiosity rover is revealing a great deal about Mars, from long-ago processes in its interior to the current interaction between the martian surface and atmosphere. Examination of loose rocks, sand, and dust has provided new understanding of the local and global processes on Mars. Analysis of observations and measurements by the rover's science instruments during the first four months after the August 2012 landing are detailed in five reports in the September 27 edition of the journal *Science*.



On Sol 84 (October 31, 2012), NASA's Curiosity rover used the Mars Hand Lens Imager (MAHLI) to capture the set of 55 high-resolution images that were stitched together to create this full-color self-portrait. Credit: NASA/JPL-Caltech/Malin Space Science Systems.

A key finding is that water molecules are bound to fine-grained soil particles, accounting for about 2% of the particles' weight at Gale Crater where Curiosity landed. This result has global implications, because these materials are likely distributed around the Red Planet. Curiosity also has completed the first comprehensive mineralogical analysis on another planet using a standard laboratory method for identifying minerals on Earth. The findings about both crystalline and noncrystalline components in soil provide clues to the planet's volcanic history.

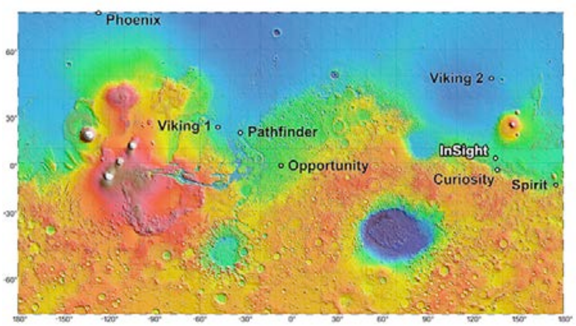
Information about the evolution of the martian crust and deeper regions within the planet comes from Curiosity's mineralogical analysis of a football-size igneous rock called "Jake M." Igneous rocks form by cooling molten material that originated well beneath the crust. The chemical compositions of the rocks can be used to infer the thermal, pressure, and chemical conditions under which they crystallized. "No other martian rock is so similar to terrestrial igneous rocks," said Edward Stolper of the California Institute of Technology, lead author of a report about this analysis. "This is surprising because previously studied igneous rocks from Mars differ substantially from terrestrial rocks and from Jake M."

The other four reports include analysis of the composition and formation process of a windblown drift of sand and dust, by David Blake of NASA's Ames Research Center at Moffett Field, California, and co-authors. Curiosity examined this drift, called Rocknest, with five instruments, preforming an onboard laboratory analysis of samples scooped up from the martian surface. The drift has a complex history and includes sand particles with local origins, as well as finer particles that sample windblown martian dust distributed regionally or even globally.

The rover is equipped with a laser instrument to determine material compositions from some distance away. This instrument found that the fine-particle component in the Rocknest drift matches the composition of windblown dust and contains water molecules. The rover tested 139 soil targets at Rocknest and elsewhere during the mission's first three months and detected hydrogen — which scientists interpret as water — every time the laser hit fine-particle material. "The fine-grain component of the soil has a similar composition to the dust distributed all around Mars, and now we know more about its hydration and composition than ever before," said Pierre-Yves Meslin of the Institut de Recherche en Astrophysique et Planétologie in Toulouse, France, lead author of a report about the laser instrument results.

A laboratory inside Curiosity used X-rays to determine the composition of Rocknest samples. This technique, discovered in 1912, is a laboratory standard for mineral identification on Earth. The equipment was miniaturized to fit on the spacecraft that carried Curiosity to Mars, and this has yielded spinoff benefits for similar portable devices used on Earth. David Bish of Indiana University in Bloomington co-authored a report about how this technique was used and its results at Rocknest. X-ray analysis not only identified 10 distinct minerals, but also found an unexpectedly large portion of the Rocknest composition is amorphous ingredients, rather than crystalline minerals. Amorphous materials, similar to glassy substances, are a component of some volcanic deposits on Earth.

Another laboratory instrument identified chemicals and isotopes in gases released by heating the Rocknest soil in a tiny oven. Isotopes are variants of the same element with different atomic weights. These tests found water makes up about 2% of the soil, and the water molecules are bound to the amorphous materials in the soil. "The ratio of hydrogen isotopes in water released from baked samples of Rocknest soil indicates the water molecules attached to soil particles come from interaction with the modern atmosphere," said Laurie Leshin of Rensselaer Polytechnic Institute in Troy, New York, lead author of a report about analysis with the baking instrument. Baking and analyzing the Rocknest sample also revealed a compound with chlorine and oxygen, likely chlorate or perchlorate, which previously was known to exist on Mars only at one high-latitude site. This finding at Curiosity's equatorial site suggests more global distribution.



The location of the cluster of semifinalist landing sites for InSight is indicated on this near-global topographic map of Mars, which also indicates landing sites of current and past NASA missions to the surface of Mars. Credit: NASA/JPL–Caltech.

NASA Evaluates Four Candidate Sites for 2016 Mars Mission

NASA has narrowed to four the number of potential landing sites for the agency's next mission to the surface of Mars, a 2016 lander to study the planet's interior. The stationary Interior Exploration Using Seismic Investigations, Geodesy and Heat Transport (InSight) lander is scheduled to launch in March 2016 and land on Mars six months later. It will touch down at one of four sites selected in August from a field of 22 candidates. All four semifinalist spots lie near each other on an equatorial plain in an area of Mars called Elysium Planitia.

"We picked four sites that look safest," said geologist Matt Golombek of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. Golombek is leading the site-selection process for InSight. "They have mostly smooth terrain, few rocks and very little slope." Scientists will focus two of NASA's Mars Reconnaissance Orbiter (MRO) cameras on the semifinalists in the coming months to gain data they will use to select the best of the four sites well before InSight is launched.

The mission will investigate processes that formed and shaped Mars and will help scientists better understand the evolution of our inner solar system's rocky planets, including Earth. Unlike previous Mars landings, what is on the surface in the area matters little in the choice of a site except for safety considerations. "This mission's science goals are not related to any specific location on Mars because we're studying the planet as a whole, down to its core," said Bruce Banerdt, InSight principal investigator at JPL. "Mission safety and survival are what drive our criteria for a landing site."

Each semifinalist site is an ellipse measuring 81 miles (130 kilometers) from east to west and 17 miles (27 kilometers) from north to south. Engineers calculate the spacecraft will have a 99% chance of landing within that ellipse, if targeted for the center.

Elysium is one of three areas on Mars that meet two basic engineering constraints for InSight. One requirement is being close enough to the equator for the lander's solar array to have adequate power at all times of the year. Also, the elevation must be low enough to have sufficient atmosphere above the site for a safe landing. The spacecraft will use the atmosphere for deceleration during descent.

All four semifinalist sites, as well as the rest of the 22 candidate sites studied, are in Elysium Planitia. The only other two areas of Mars meeting the requirements of being near the equator at low elevation, Isidis Planitia and Valles Marineris, are too rocky and windy. Valles Marineris also lacks any swath of flat ground large enough for a safe landing.

InSight also needs penetrable ground, so it can deploy a heat-flow probe that will hammer itself 3 to 5 yards (2.7 to 4.6 meters) into the surface to monitor heat coming from the planet's interior. This tool can penetrate through broken-up surface material or soil, but could be foiled by solid bedrock or large rocks. "For this mission, we needed to look below the surface to evaluate candidate landing sites," Golombek said.

InSight's heat probe must penetrate the ground to the needed depth, so scientists studied MRO images of large rocks near martian craters formed by asteroid impacts. Impacts excavate rocks from the subsurface, so by looking in the area surrounding craters, the scientists could tell if the subsurface would have probe-blocking rocks lurking beneath the soil surface. InSight also will deploy a seismometer on the surface and will use its radio for scientific measurements. For more information about the mission, visit *insight.jpl.nasa.gov*.

India's Mars Orbiter Mission Successfully Leaves Earth Orbit

India's Mars Orbiter Mission was launched onboard a PSLV-C25 launch vehicle on November 5, 2013. The orbiter successfully left Earth's sphere of influence on December 1 on its way toward the Red Planet.

Reaching a major milestone in the country's space history, the Indian Space Research Organization's (ISRO) Mars Orbiter Mission successfully left Earth's sphere of influence on its way toward the Red Planet. The critical maneuver to place the spacecraft in the Mars transfer trajectory was successfully carried out at 19:19 UTC on November 30. "Following the completion of this maneuver, the Earth orbiting phase of the spacecraft ended. The spacecraft is now on a course to encounter Mars after a journey of about 10 months around the Sun," the Bangalore-headquartered ISRO said in a statement.

India launched its first spacecraft bound for Mars on November 5, a complex mission that it hopes will demonstrate and advance technologies for space travel. The 1350-kilogram (3000-pound) orbiter Mangalyaan, which means "Mars craft" in Hindi, must travel 780 million kilometers (485 million miles) over 300 days to reach an orbit around Mars next September. If the mission is successful, India will become only the fourth space program to visit the Red Planet after the Soviet Union, the United States, and Europe.

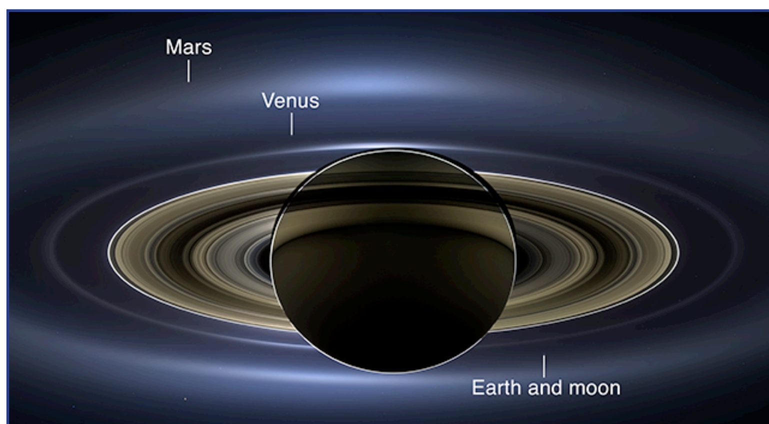
Some have questioned the $72 million price tag for a country of 1.2 billion people still dealing with widespread hunger and poverty. But the government defended the Mars mission, and its $1 billion space program in general, by noting its importance in providing high-tech jobs for scientists and engineers and practical applications in solving problems on Earth. Decades of space research have allowed India to develop satellite, communications, and remote sensing technologies that are helping to solve everyday problems at home, from forecasting where fish can be caught by fishermen to predicting storms and floods.

One of the primary objectives of the first Indian mission to Mars is to develop the technologies required for design, planning, management, and operations of an interplanetary mission. In addition, the orbiter will gather images and data that will help in determining how martian weather systems work and what happened to the large quantities of water that are believed to have once existed on Mars. It also will search Mars for methane, a key chemical in life processes that could also come from geological processes. Experts say the data will improve understanding about how planets form, what conditions might make life possible, and where else in the universe it might exist.

The orbiter is expected to have at least six months to investigate the planet's landscape and atmosphere. At its closest point, it will be 365 kilometers (227 miles) from the planet's surface, and its furthest point will be 80,000 kilometers (49,700 miles) away. For more information about the mission, visit *www.isro.org/pslv-c25/mission.aspx*.

NASA Cassini Spacecraft Provides New View of Saturn and Earth

NASA has released a natural-color image of Saturn from space, the first in which Saturn, its moons and rings, and Earth, Venus, and Mars are all visible. The new panoramic mosaic of the majestic Saturn system taken by NASA's Cassini spacecraft, which shows the view as it would be seen by human eyes, was unveiled at the Newseum in Washington on November 12.



On July 19, 2013, in an event celebrated the world over, NASA's Cassini spacecraft slipped into Saturn's shadow and turned to image the planet, seven of its moons, its inner rings — and, in the background, our home planet, Earth. Credit: NASA/JPL-Caltech/SSI.

Cassini's imaging team processed 141 wide-angle images to create the panorama. The image sweeps 404,880 miles (651,591 kilometers) across Saturn and its inner ring system, including all of Saturn's rings out to the E ring, which is Saturn's second outermost ring. For perspective, the distance between Earth and our Moon would fit comfortably inside the span of the E ring.

"In this one magnificent view, Cassini has delivered to us a universe of marvels," said Carolyn Porco, Cassini's imaging team lead at the Space Science Institute in Boulder, Colorado. "And it did so on a day people all over the world, in unison, smiled in celebration at the sheer joy of being alive on a pale blue dot."

The mosaic is part of Cassini's "Wave at Saturn" campaign, where on July 19, people for the first time had advance notice that a spacecraft was taking their picture from planetary distances. NASA invited the public to celebrate by finding Saturn in their part of the sky, waving at the ringed planet and sharing pictures over the Internet.

An annotated version of the Saturn system mosaic labels points of interest. Earth is a bright blue dot to the lower right of Saturn. Venus is a bright dot to Saturn's upper left. Mars also appears, as a faint red dot, above and to the left of Venus. Seven saturnian moons are visible, including Enceladus on the left side of the image. Zooming into the image reveals the moon and the icy plume emanating from its south pole, supplying fine, powder-sized icy particles that make up the E ring.

The E ring shines like a halo around Saturn and the inner rings. Because it is so tenuous, it is best seen with light shining from behind it, when the tiny particles are outlined with light because of the phenomenon of diffraction. Scientists who focus on Saturn's rings look for patterns in optical bonanzas like these. They use computers to dramatically increase the contrast of the images and change the color balance, for example, to see evidence for material tracing out the full orbits of the tiny moons Anthe and Methone for the first time.

"This mosaic provides a remarkable amount of high-quality data on Saturn's diffuse rings, revealing all sorts of intriguing structures we are currently trying to understand," said Matt Hedman, a Cassini participating scientist at the University of Idaho in Moscow. "The E ring in particular shows patterns that likely reflect disturbances from such diverse sources as sunlight and Enceladus' gravity."

Cassini does not attempt many images of Earth because the Sun is so close to our planet that an unobstructed view would damage the spacecraft's sensitive detectors. Cassini team members looked for an opportunity when the Sun would slip behind Saturn from Cassini's point of view. A good opportunity came on July 19, when Cassini was able to capture a picture of Earth and its Moon, and this multi-image, backlit panorama of the Saturn system.

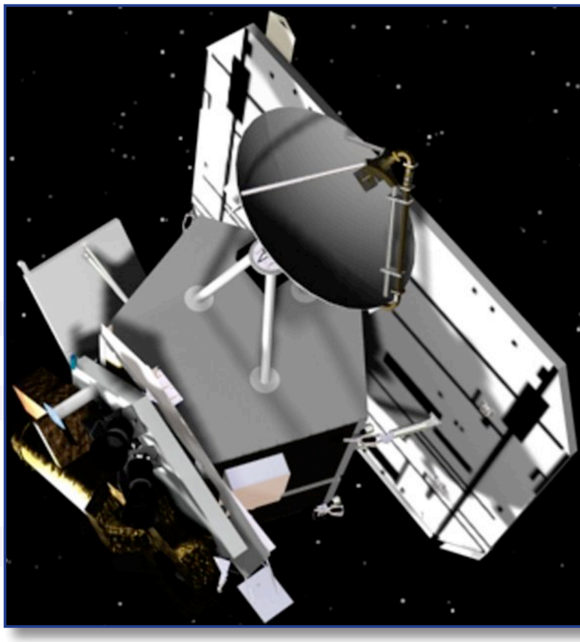
"With a long, intricate dance around the Saturn system, Cassini aims to study the Saturn system from as many angles as possible," said Linda Spilker, Cassini project scientist based at NASA's Jet Propulsion Laboratory in Pasadena, California. "Beyond showing us the beauty of the Ringed Planet, data like these also improve our understanding of the history of the faint rings around Saturn and the way disks around planets form — clues to how our own solar system formed around the Sun."

Launched in 1997, Cassini has explored the Saturn system for more than nine years. NASA plans to continue the mission through 2017, with the anticipation of many more images of Saturn and its rings and moons, as well as other scientific data. For more information, visit *saturn.jpl.nasa.gov*.

Deep Impact Mission Ends, Leaves Bright Comet Tale

In September, NASA announced the end of operations for the Deep Impact spacecraft, history's most traveled deep-space comet hunter, after trying unsuccessfully for more than a month to regain contact with the spacecraft. University of Maryland (UMD) scientists — who helped conceive the mission, bring it to reality, and keep it going years longer than originally planned — say it is a big loss, but find great satisfaction that Deep Impact exceeded all expectations and that the science derived from it transformed our understanding of comets.

"The impact on Comet Tempel 1, the flyby of Comet Hartley 2, and the remote sensing of Comet Garradd have led to so many surprising results that there is a complete rethinking of our understanding of the formation of comets and of how they work. These small, icy remnants of the formation of our solar system are much more varied, both one from another and even from one part to another of a single comet, than we had ever anticipated," said UMD astronomer Michael A'Hearn, who led the Deep Impact science



Artist's drawing of the flyby spacecraft for the Deep Impact Mission. The spacecraft carried a solar panel, high-gain antenna, self-guided impactor, debris shield, and science instruments for high and medium resolution imaging, infrared spectroscopy, and optical navigation, and had a total mass of 1020 kilograms. Credit: Ball Aerospace & Technologies Corp.

team from the successful Deep Impact proposal to its unanticipated completion. "Deep Impact has been a principal focus of my astronomy work for more than a decade and I'm saddened by its functional loss. But, I am very proud of the many contributions to our evolving understanding of comets that it has made possible."

Deep Impact first made history and world-wide headlines on July 4, 2005 when a small impactor spacecraft — a refrigerator-sized probe released from the main craft — collided spectacularly with Comet Tempel 1 at 23,000 miles per hour to give scientists their first-ever view of pristine material from inside a comet.

A comet is composed of dust and ices and that form its body (nucleus) and tail (coma). The tail is created when heat from the Sun causes the body of the comet to give off dust and ice, forming a cloud that surrounds and extends out from the nucleus. According to A'Hearn, the key goal of the Deep Impact's mission to Tempel 1 was to look for differences between the composition of the Sun-heated surface of a comet's nucleus and its colder, more primordial interior. "Much to our surprise, and contrary to most theoretical models, the different ices [of water, carbon dioxide and carbon monoxide] that were excavated from as deep as 20 meters had the same relative abundances as the ones that were evaporating just below the surface," he said.

A'Hearn noted that science results of this mission also showed comets could be surprisingly fluffy. "We found that the nucleus of Tempel 1 as a whole is at least 50% empty space and the surface layer at the impact site at least 75% empty space. This finding confirmed the correctness of some previous indirect observations suggesting comets could be more porous than expected." And he said the wide variety of craters and other surface features, and particularly the prominent layering of the nucleus found on this comet imply that the nuclei of short-period comets (those which orbit the Sun every 20 years or less) are not fragments of larger bodies as had been argued by many scientists.

After the original mission was complete, the UMD-led science team convinced NASA to keep the spacecraft operational and consider new mission proposals. Working with scientists from the NASA Goddard Spaceflight Center, they ultimately created two missions in one. The Deep Impact spacecraft and its three working instruments (two color cameras and an infrared spectrometer) headed for an extended flyby of Comet Hartley 2. Along the way, Deep Impact's high resolution camera searched for Earth-sized planets around other stars.

This extended mission culminated in the successful flyby of Comet Hartley 2— one of a small subset of known, hyperactive comets —on November 4, 2010, during which the spacecraft flew through and imaged a "snow storm" of large and small fluffy ice particles. The team's analysis showed carbon dioxide was the volatile fuel generating the ice spewing jets that created this cosmic snow cloud.

In January 2012, the Deep Impact teams used the spacecraft's instruments for a distant campaign studying Comet Garradd. After spending some 4 billion years in the Siberia of the solar system, a distant, frozen region known as the Oort cloud, the comet was making one of its first few passages close to the Sun. Observations of Garradd led UMD and other scientists to reexamine the behavior of frozen gases in comets and the gas jets that result when these ices are warmed by the Sun. In 2013 the Deep Impact team was using the spacecraft to study another comet on its first time visitor from the Oort cloud to the inner solar system, Comet ISON. This study-from-a-distance campaign was cut short by the failure of the spacecraft.

"The core of the Deep Impact mission was a controlled planetary-scale impact experiment, but in the end it was so much more," said UMD astronomer and Deep Impact mission scientist Jessica Sunshine. "Deep Impact treated us to views of beautiful landscapes including flows, cliffs, and spires that we could never have imagined, flew us through a cloud of ice surrounding Hartley 2, and along the way also confirmed that the surface of the Moon is hydrated. The new perspective and the new series of questions raised by Deep Impact has inspired us to propose a new mission to understand the diversity of comets that Deep Impact revealed. Comet Hopper (CHopper) would be a cometary rover that would not be limited to tantalizing data from flyby comets. Instead it would explore a comet in detail, hopping from landform to landform, as the comet moves from the outer to the inner solar system."

Johns Hopkins Applied Physics Lab Launches New Generation of Small Satellites: Experimental "Cubesats" Designed for Range of National Security, Science Missions

On November 19, The Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, introduced a new generation of small satellites with the launch of two experimental "cubesats" designed for a range of national security and space science operations. The cubesats were among 29 satellites lifted to orbit onboard a Minotaur I rocket from Wallops Flight Facility, Virginia, at 8:15 p.m. EST, as part of the U.S. Air Force ORS-3 mission. APL mission operators confirmed radio contact with the two satellites just before 10:00 p.m. that evening.

A Johns Hopkins Applied Physics Laboratory (APL) technician prepares the twin Multimission Bus Demonstration satellites — the first cubesats designed and built at APL — for testing. Credit: JHU/APL.

The shoebox-sized satellites, part of APL's Multimission Bus Demonstration (MBD) (and designated ORS Tech 1 and ORS Tech 2 for the November launch), represent a new capability for the military and intelligence and science communities — a small satellite that can get to space inexpensively and be tough enough for long-term use. "The Multimission Bus Demonstration could revolutionize the field of small satellites and their potential uses," says Joe Suter, APL's mission area executive for National Security Space. "There are applications for DoD agencies that want quick access to space, with durable satellites you can launch for a fraction of what it costs to launch larger spacecraft. MBD can be very significant contribution to those missions."

Because they cost relatively little to build, launch, and operate, small satellites (commonly known as cubesats or "microsats") are especially popular among university researchers looking to study the space just above Earth. But the spacecraft are effectively science projects, not dependable or durable enough for military or intelligence community use. The APL cubesat tackles this challenge, drawing from five decades of APL experience in building rugged spacecraft for harsh environments near and far from

Earth — and from the APL's deep, unique understanding of spacecraft, aerospace engineering, and applied engineering techniques. The satellites have all the subsystems of a standard orbiter — command and data handling, communications, navigation, power, and payload — scaled to fit into a 34-by-10-by-10 centimeter (about 13-by-4-by-4 inch) package that weighs less than 5 kilograms (11 pounds).

The satellites also have other touches of APL ingenuity and resourcefulness. For example, engineers had to invent solar-panel release mechanisms that didn't include pyrotechnics, since microsats, as secondary or "piggy back" payloads on other launches, aren't permitted to carry explosives. Once deployed, the solar panels themselves have three jobs. Besides supplying power, they act as reflectors for the satellite's antennas, and the magnetic field produced from the internal torque coils are used to align the spacecraft. A critical feature is that the satellite can be customized to fit mission needs, and instrument builders can add any payload that fits within the spacecraft's size, power, and interface specifications.

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: February 14, 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*.

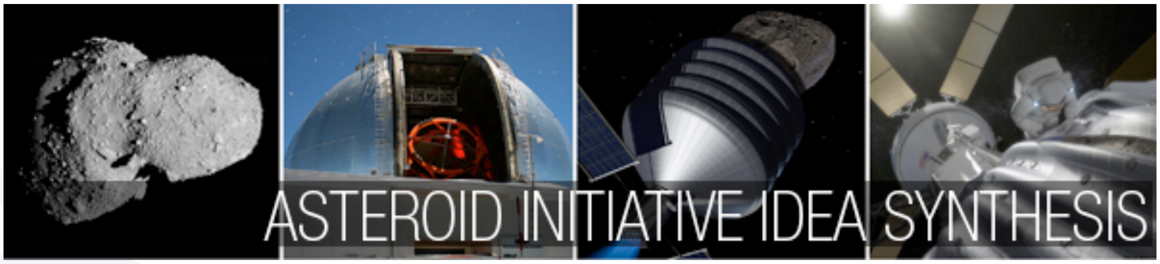
The *Bulletin* is published quarterly by the Lunar and Planetary Institute (LPI), 3600 Bay Area Boulevard, Houston TX 77058. Material in this issue may be copied without restraint for library, abstract service, education, or personal research purposes.

ISSN 1534-6587

The LPI is operated by the Universities Space Research Association under Award No. NNX08AC28A from the Science Mission Directorate of the National Aeronautics and Space Administration. Any opinions, findings, and conclusions or recommendations expressed in this issue are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

Asteroid Initiative Ideas Synthesis Workshop

September 30, 2013, and November 20–22, 2013, Houston, Texas



NASA's asteroid initiative is developing mission concepts for capturing a small near-Earth asteroid and redirecting it into a stable orbit around the Moon. Astronauts launched onboard the Orion spacecraft would rendezvous with the asteroid in lunar orbit and collect samples for return to Earth. The asteroid initiative also consists of the Asteroid Grand Challenge, "to find all asteroid threats to human populations and know what to do about them."

In June, NASA issued a Request for Information (RFI) to gather innovative ideas that the agency will use to plan the asteroid initiative. The RFI was open to everyone, including individuals, companies, universities, government agencies, and international organizations. More than 400 responses were received from 16 countries. All responses were evaluated for relevance, impact, maturity, and affordability, and 96 of the most promising ideas were selected for presentation at the Asteroid Initiative Ideas Synthesis Workshop.

The purpose of this workshop was to identify ideas that could be incorporated into mission plans, assess any technology development needed to mature the ideas, and synthesize related ideas to help with mission and system integration. The workshop participants also made recommendations for further studies and next steps.

The workshop was held in two parts at the Lunar and Planetary Institute in Houston, Texas. The first part was completed on September 30 before the government shutdown, and approximately 130 people attended. The workshop resumed on November 20–22, and approximately 120 people attended the second part. Nearly 2000 people were able to participate virtually. The workshop sessions included presentations and discussion in the following areas:

- Asteroid Characterization
- Asteroid Redirect Systems
- Asteroid Deflection Demonstrations
- Asteroid Capture Systems
- Crew Systems for Asteroid Exploration
- Partnerships and Participatory Engagement
- Crowdsourcing and Citizen Science
- Next-Generation Engagement

A final report of the workshop findings and recommendations will be published in late January. For more information about the Asteroid Initiative Ideas Synthesis Workshop, including videos and presentations, visit *www.nasa.gov/asteroidworkshop*.

Apollo Lunar Surface Experiments Package (ALSEP) Documents Available Online

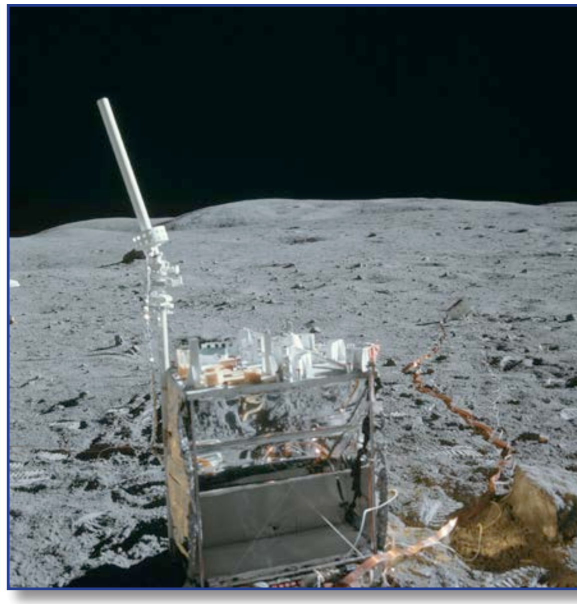
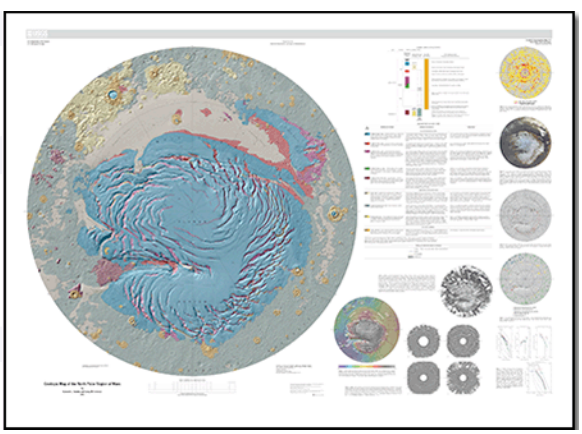


Photo of the Central Station from Apollo 16's ALSEP. The Central Station was essentially the command center for the entire ALSEP station. It received commands from Earth, transmitted data, and distributed power to each experiment. Credit: NASA.

As part of its work on a NASA-funded Apollo Lunar Surface Experiments Package (ALSEP) data recovery project, the Lunar and Planetary Institute (LPI) has scanned a collection of ALSEP-related documents. This archive focuses on the development, deployment, and operation of the ALSEP experiments and currently includes 210 documents with more than 17,700 pages of material. ALSEP comprised a set of scientific instruments placed by the astronauts at the landing site of each of the five Apollo missions to land on the Moon following Apollo 11 (Apollos 12, 14, 15, 16, and 17). Apollo 11 left a smaller package called the Early Apollo Scientific Experiments Package (EASEP).

These documents include ALSEP Systems Handbooks for several of the ALSEP arrays, ALSEP Data Processing Procedures, the ALSEP Archive Tape Description Document, and daily status reports for the ALSEP network from initial deployment in 1969 to termination in 1977. The documents can be searched based on key words selected by the user. This material is available as part of the LPI's Lunar Science and Exploration Portal at *www.lpi.usra.edu/lunar/ALSEP*.

Material on this website provides important background information about the ALSEP experiments that may be useful to individuals who are reanalyzing data obtained from the experiments. However, the archive does not include science results from these experiments. LPI intends to continue adding other ALSEP-related material to the website on an ongoing basis.



Geologic Map of the North Polar Region of Mars

The Geologic Map of the North Polar Region of Mars by Kenneth Tanaka and Corey Fortezzo is available online on the United States Geological Survey (USGS) website at *pubs.usgs.gov/sim/3177/*. Also available at the site is a description and informational pamphlet.

This geologic map of Planum Boreum is the first to record its entire observable stratigraphic record using the various post-Viking image and topography datasets released before 2009. Provided in the map is more detail than previously published, including some substantial revisions based on new data and observations. The available data have increased and improved immensely in quantity, resolution, coverage, positional accuracy, and spectral range, enabling the authors to resolve previously unrecognized geomorphic features, stratigraphic relations, and compositional information. More carefully prescribed and effective mapping methodologies and digital techniques were employed in the creation of the map, as well as formatting guidelines. The foremost aspect to the mapping approach is how geologic units are discriminated based primarily on their temporal relations with other units as expressed in unit contacts by unconformities or by gradational relations. Whereas timing constraints of such activity in the north polar region are now better defined stratigraphically, they remain poorly constrained chronologically. The end result is a new reconstruction of the sedimentary, erosional, and structural histories of the north polar region and how they may have been driven by climate conditions; available geologic materials; and eolian, periglacial, impact, magmatic, hydrologic, and tectonic activity.

LPI Summer Intern Program in Planetary Science

The Lunar and Planetary Institute (LPI) invites undergraduates with at least 50 semester hours of credit to experience cutting-edge research in the lunar and planetary sciences. As a Summer Intern, you will work one-on-one with a scientist at the LPI or at the NASA Johnson Space Center on a research project of current interest in lunar and planetary science. Furthermore, you will participate in peer-reviewed research, learn from top-notch planetary scientists, and preview various careers in science.

The 10-week program runs from June 2 through August 8, 2014. Interns will receive a $5000.00 stipend plus $1000.00 U.S. travel stipend, or $1500.00 foreign travel reimbursement for foreign interns.

The LPI is located near Johnson Space Center, on the south side of Houston, Texas. The LPI provides, on NASA's behalf, leadership in the scientific community for research in lunar, planetary, and solar system sciences, and linkage with related terrestrial programs.

The deadline for applying for the 2014 program is **Friday, January 17, 2014**. For more information, including eligibility and selection criteria, areas of research, and an online application form, please visit *www.lpi.usra.edu/lpiintern.*

Graduate Students Eligible for the LPI Career Development Award

LPI Career Development Award

The Lunar and Planetary Institute (LPI) is proud to announce its seventh LPI Career Development Award, which is open to both U.S. and non-U.S. applicants. This award will be given to graduate students who have submitted a first-author abstract for presentation at the 45th Lunar and Planetary Science Conference (LPSC). A travel stipend of $1000.00 will be awarded to the top applicants to help cover travel expenses for attending the LPSC in March. Awards will be based on a review of the application materials by a panel of lunar and planetary scientists.

Applications must include a letter outlining why the applicant would like to participate at the LPSC and what he or she will contribute to the conference, a letter of recommendation from his or her research advisor, a copy of the first-author abstract, and a curriculum vitae for the applicant.

Applications and all accompanying materials must be submitted electronically. All documents uploaded must be in text or PDF format. For more information and a link to the application form, visit *www.hou.usra.edu/meetings/lpsc2014/cdaAward*.

Texas Community College Aerospace Scholars

This program provides an opportunity for Texas community college students to learn more about what NASA does and how they can become a part of the exciting future of space exploration! Texas Community College Aerospace Scholars is a program funded by the Texas legislature and administered by NASA Johnson Space Center (JSC). Community college students who are interested in the areas of science, technology, engineering, and mathematics will apply to travel to NASA Johnson Space Center (JSC) for a three-day experience. This opportunity will provide a hands-on project featuring engineering career possibilities. Selected students will begin the semester commitment with web-based preparation prior to visiting JSC. The three-day experience at JSC will allow participants to participate in a team project directed by NASA engineers; attend engineer, scientist, and astronaut briefings; tour NASA JSC facilities; and interact with community college students from across the nation.

The application deadline is **January 21, 2014**. For more information, visit *cas.aerospacescholars.org*.

NASA's Planetary Geology and Geophysics Undergraduate Research Program

Through the Planetary Geology and Geophysics Undergraduate Research Program (PGGURP) qualified undergraduates are paired with NASA-funded investigators at research locations around the United States for eight weeks during the summer. PGGURP's goals are to provide incentive and development of future planetary geoscientists; broaden the base of students who participate in planetary geoscience; introduce students interested in the traditional sciences to planetary science; and give potential planetary geoscientists a chance to explore the exciting field of planetary research. Students will spend the summer at the NASA scientist's home institution, and the program will pay for housing, travel, and a cost-of-living stipend.

The program consists of an eight-week summer internship, in which qualified students are matched with a NASA-funded planetary scientist. Care is taken to match the skills of the student with the needs of the NASA mentor.

The application deadline is **February 3, 2014**. For more information, visit *www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships

Caltech's Summer Undergraduate Research Fellowships (SURF) program introduces students to research under the guidance of seasoned research mentors at the California Institute of Technology (Caltech) and the Jet Propulsion Laboratory (JPL). Students experience the process of research as a creative intellectual activity. SURF is modeled on the grant-seeking process: students collaborate with potential mentors to define and develop a project; applicants write research proposals for their projects; a faculty committee reviews the proposals and recommends awards; students carry out the work over a 10-week period in the summer, mid-June to late August; and at the conclusion of the program, they submit a technical paper and give an oral presentation at SURF Seminar Day, a symposium modeled on a professional technical meeting.

The deadline for all application materials is **February 22, 2014.** For more information, visit *www.surf.caltech.edu.*

Internships, Scholarships, Fellowships with NASA

The NASA One Stop Shopping Initiative (OSSI) strives to provide high-school students and undergraduate and graduate students at all institutions of higher education access to a portfolio of internship, fellowship, and scholarship opportunities offered by NASA mission directorates and centers.

Visit the Office of Education Infrastructure Division LaunchPad to find information on internship, fellowship, and scholarship opportunities. The site features the OSSI online application for recruiting NASA Interns, Fellows, and Scholars (NIFS). This innovative system allows students to search and apply for all types of higher-education NASA internship, fellowship, and scholarship opportunities in one location. A single application places the student in the applicant pool for consideration by all NASA mentors.

Applications for summer 2014 opportunities are due **March 1, 2014**. To find available opportunities and to fill out an OSSI online application for recruiting NIFS, visit *intern.nasa.gov*. Inquiries about the OSSI should be submitted via *intern.nasa.gov/oic*.

Postdoctoral and Graduate Fellowships at the Smithsonian

The Department of Mineral Sciences at the Smithsonian Institution–National Museum of Natural History (NMNH) invites applications for both postdoctoral and graduate fellowships. Active areas of research include volcanology, mineral spectroscopy, geomicrobiology, environmental mineralogy, geochemistry, experimental petrology, mineral physics, meteorite studies, solar system formation, and planetary formation and evolution. The department also houses the National Meteorite Collection, the National Rock and Ore Collection, the National Gem and Mineral Collection, and the Global Volcanism Program. A description of facilities, staff profiles, and collection resources can be found at *mineralsciences.si.edu.*

Predoctoral and postdoctoral candidates can request up to 12 or 24 months, respectively, through the Smithsonian Institution Fellowship Program. Graduate fellowships through this program are funded for 10 weeks. Additional fellowship opportunities are available through the recently established Peter Buck Fellowship Program at NMNH; postdoctoral fellowships are for 2–3 years and graduate fellowships are 1–2 years. Applications may be submitted to both competitions. Additional information is available at *www.si.edu/ofg*. The application deadline is **January 15, 2014**.

SAO Summer Intern Program

The Smithsonian Astrophysical Observatory (SAO) Summer Intern Program is a Research Experiences for Undergraduates (REU) program where students work on astrophysics research with an SAO/Harvard scientist. In 2014 the program will run for 10 weeks, likely from June 8 through August 15, pending the availability of Harvard housing. Students are expected to be in residence at the Harvard-Smithsonian Center for Astrophysics (CfA) for the full duration of the program.

The program is funded by the National Science Foundation and the Smithsonian Institution. Undergraduate students interested in a career in astronomy, astrophysics, physics, or related physical sciences are encouraged to apply for the 2014 program. Applicants must be U.S. citizens or permanent residents ("green card" holders), and must be enrolled in a degree program leading to a bachelor's degree. Seniors who will graduate in June 2014 (or before) are not eligible.

The application deadline is **February 3, 2014**. For more details, visit *hea-www.harvard.edu/REU/REU.html*.

NASA Minority Innovation Challenges Institute

The mission of the Minority Innovation Challenges Institute (MICI) is to create a virtual training ground where minority undergraduate students learn how to compete in NASA technical challenges for both prestige and significant cash prizes. This NASA funded program, which is managed by Florida Agricultural & Mechanical University (FAMU), provides a year-round virtual conference platform where students from across the country can participate in free interactive educational sessions of their choosing. Many of the sessions will focus on competitions found within NASA's Centennial Challenges program, which provides cash prizes ranging from $50,000 to $2 million to individuals/teams that can achieve specific technical accomplishments.

In addition to Centennial Challenges, students will also learn how to compete in other NASA-sponsored competitions created specifically for universities. The goal of MICI is to use NASA technical competitions as a way to inspire minority undergraduate students to pursue (1) an advanced degree in Science, Technology, Engineering, and Mathematics (STEM), and (2) a career in STEM-related disciplines that will ultimately contribute to NASA's future technological needs.

Registration to MICI is always open throughout the year. There are no cut-off dates because new content is being featured each month. For more information, visit *nasamici.com*.

Internship Program Available at APL

The Johns Hopkins University Applied Physics Laboratory (APL) is offering summer projects for students interested in working on NASA missions or space-related research opportunities at APL. Students participating in the program will work at APL, and will make critical contributions to current and future missions or grants during their assignments in the Space Department. APL is a not-for-profit center for engineering, research, and development, and a division of one of the world's premier research universities, Johns Hopkins. The 399-acre campus, 20 miles north of Washington, DC, is home to 4100 men and women who work on more than 400 programs that protect our homeland and advance the nation's vision in research and space science.

APL's Civilian Space Business Area makes critical contributions to the missions of its major sponsor, NASA, to meet the challenges of space science. They conduct research and space exploration; develop and apply space science, engineering, and technology — including the production of one-of-a-kind spacecraft, instruments, and subsystems — and focus primarily on the science discipline of space physics and planetary science. APL has built instruments and spacecraft to destinations such as Pluto, Mercury, the Sun, and our Moon. Continuing these challenges, APL is supporting NASA as it implements initiatives to explore the reaches of our solar system.

Students will receive a stipend for the 10-week program, and housing will be provided. Talks by key mission engineers and scientists, along with tours of APL and NASA/Goddard, will be provided throughout the summer. Students must be U.S. citizens, and have successfully passed a background check of criminal, social security, and driving record.

The deadline for applications is **January 27, 2014.** For more information, visit *www.aplapp.com*.

Spotlight on Education

"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 at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 17–21, 2014. There will be a variety of events and opportunities that will be of interest to the E/PO community and scientists who are involved in — or are interested in — education and outreach. The E/PO community is invited to submit poster abstracts; the deadline for submission is Tuesday, January 7, 2014. For more information and details about the conference and E/PO events, visit *www.hou.usra.edu/meetings/lpsc2014.*

NASA YSS Undergraduate Planetary Science Research Conference —
The NASA YSS Undergraduate Planetary Science Research Conference is again being hosted in conjunction with LPSC. Some travel support will be available to students who qualify. Priority will be given to students of diverse backgrounds. To receive support, students must attend the entire Undergraduate Planetary Science Research Conference and present a poster. Students are encouraged to attend LPSC and any travel support can be applied to registration for and participation in LPSC.

More information, including the date, time, location, and an application form, will be available soon. For additional information, please contact Andrew Shaner at *shaner@lpi.usra.edu.*

Plans for other E/PO events at LPSC are underway. Details about these events will be posted on the conference website as they become available.

Resource Guides on Music and on Apps

An annotated guide presenting 133 pieces of music inspired by astronomical ideas (organized into 22 topical categories such as black holes, planets, etc.) is archived in *Astronomy Education Review.* Both classical and popular music are included. Visit the website at *aer.aas.org/resource/1/aerscz/v11/i1/p010303_s1?view=fulltext.*

An annotated overview of 98 astronomy applications for smart phones and tablets has also been published in *Astronomy Education Review* and features brief descriptions and direct URLs. The listing includes a variety of apps for displaying and explaining the sky above you (some using the GPS function in your device); a series of astronomical clocks, calculators, and calendars; sky catalogs and observing planners; planet atlases and globes; citizen science tools and image displays; a directory of astronomy clubs in the U.S.; and even a graphic simulator for making galaxies collide. A number of the apps are free, and others cost just a dollar or two. A brief list of articles featuring astronomy app reviews is also included. For more information, visit *scitation.aip.org/content/aas/journal/aer/10/1/10.3847/AER2011036*.

Planetary Science News Source

As a resource to the planetary science and education community, the Lunar and Planetary Institute is regularly posting news under a range of categories, such as community announcements, mission news, funding opportunities, science news, education and public outreach, and more. A recent addition to the site is the ability to search by categories. Planetary News is available online at *www.lpi.usra.edu/planetary_news.*

Video About Interesting Studies of College Astronomy Teaching

At this summer's Astronomical Society of the Pacific meeting, Douglas Duncan (University of Colorado) and Alex Rudolph (California State Polytechnic University, Pomona) participated in a plenary session, answering such questions as, "What do learning surveys tell us about the best teaching practices?" "Are students really the multitaskers they profess to be?" "Does student addiction to electronic devices and their in-class use impact learning outcomes?" Watch the video at *www.youtube.com/watch?v=DR7pqOjg154.*

Nominate a Scientist or Educator for an AGU Award

AGU's Spilhaus Award —

This is awarded not more than once annually to an individual AGU member for devoting portions of their career to conveying to the general public the excitement, significance, and beauty of Earth and space sciences. More information is available at *honors.agu.org/medals-awards/athelstan-spilhaus-award*. Nominations open January 15 and close March 15.

Excellence in Geophysical Education Award —

This is awarded not more than once annually to an individual, group, or team. The award is to acknowledge a sustained commitment to excellence in geophysical education by a team, individual, or group; to educators who have had a major impact on geophysical education at any level (kindergarten through postgraduate), who have been outstanding teachers and trainers for a number of years, or who have made a long-lasting, positive impact on geophysical education through professional service. More information is available at *honors.agu.org/medals-awards/excellence-in-geophysical-education-award*. Nominations open January 15 and close March 15.

2014 Edward C. Roy Jr. Award for Excellence in K–8 Earth Science Teaching

Each year, the American Geological Institute (AGI) recognizes one full-time U.S. teacher from kindergarten through eighth grade for leadership and innovation in Earth science education through the Edward C. Roy Jr. Award. The winner will receive a $2500 prize and a travel grant of $1000 to attend the National Science Teachers Association (NSTA) Annual Conference in April 2014 in Boston to accept the award. To be eligible for the 2014 competition, applications must be postmarked by January 10, 2014. For more information, visit *www.agiweb.org/education/awards/ed-roy*.

Bruce Murray. Credit: The Planetary Society.

Bruce Murray, 1931–2013

One of the most remarkable minds of twentieth-century exploration was stilled on August 29, 2013, when Bruce C. Murray died of Alzheimer's disease at the age of 81. The Planetary Society owes its existence to Murray, who with Carl Sagan, decided in 1979 that the world needed an organization that would harness the public's fascination with planetary exploration and demonstrate to politicians that voters would support those who supported planetary exploration. Murray and Sagan directed the organization together for 16 years, until Sagan's death, and Murray took over as president for another 5 years.

The world knew Murray as Director of the Jet Propulsion Laboratory in Pasadena, from the triumphant Viking landings on Mars, through Voyager's encounters at Jupiter and Saturn, to the start of Galileo to Jupiter and Magellan to Venus. *Discover* magazine dubbed him "the Admiral of the Solar System," a title for which he took a lot of teasing from those who knew and loved him. Murray's great hero was Captain James Cook, the great explorer of the seas, and he may have been secretly pleased to have been given a title — even if entirely unofficial — that recalled great explorers of the past.

As a young man, Murray did not set out to become a planetary explorer. He participated in the ROTC program while a student at the Massachusetts Institute of Technology (MIT), and after receiving his Ph.D. in geology, he served two years with the U.S. Air Force. He then spent several years prospecting for petroleum for Standard Oil. He found his way to the California Institute of Technology (Caltech) where, in the early 1960s, geologists were beginning to look at Earth's neighboring ball of rock, sometimes called the Moon, as an object worthy of study.

Murray became a pioneer in planetary imaging and earned an appointment as a professor of Geological and Planetary Sciences at Caltech. He began his Caltech career by using big telescopes, such as the 200-inch Hale telescope on Palomar Mountain, to observe the Moon and Mars through the infrared to try to figure out what substances lay on their surfaces. As the space age progressed and people started launching spacecraft to get close to the planets under study, Murray was appointed to the Imaging Team for the first Mariner missions to Mars. His skills in imaging, wrangling fellow scientists, and communicating with the public led to his appointment as Imaging Team Leader for the Mariner 10 mission to Mercury. Not long after that success, he was appointed Director of the Jet Propulsion Laboratory.

Murray profoundly influenced the course of planetary exploration from the very beginnings of the space age. It is through its spectacular images of other worlds that the space program has captured the hearts and imaginations of members of the public. Few know that, without Murray, there might not be so many wondrous images to entrance us. In the early days of planetary exploration, the idea of taking along a camera to snap pictures of the planets was controversial. The space science community was dominated by physicists who thought taking pictures was a public relations stunt that would eat up data, spacecraft power, and mass resources that should be reserved for other instruments that they found more scientifically valuable. Working with his colleagues at Caltech, notably Robert Leighton and Robert Sharp (for whom Mt. Sharp is named on Mars), Murray changed that. He literally helped change our picture of the solar system.

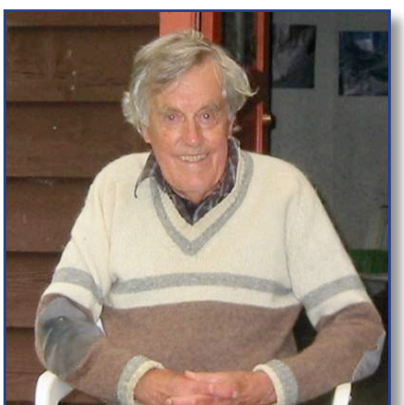
The planet Earth, especially the dry desert areas that entrance many a geologist, was also a target for Murray's scientific ponderings, even while he led the charge to Mercury, Venus, Mars, and beyond. Through his work on so many worlds, Murray helped invent the field of comparative planetology. Those scientists who today study planetary processes such as seismic events, climate change, the history of water, cratering, and so on by comparing them among different worlds are following in his footsteps.

While Murray had a reputation for suffering fools badly — a trait his mother frequently lectured him about — he was remarkably willing to change his mind and admit when he was wrong. In his scientific work, he was willing to overcome his skepticism about the accessibility of water on Mars. His rigorous insistence on intellectual honesty often made him controversial, especially when dealing with the often contentious politics of the space program. But those same qualities made him widely admired and sought after for advice on the direction the space program should take into the future.

Murray's most visible legacy may lie with the institutions with which he was principally associated — Caltech, JPL, and The Planetary Society — but his biggest legacy is the outstanding group of planetary scientists who were once his students. So many of the great discoveries of the last few decades of planetary science have been made by those who were trained in their work by this demanding, gruff, brilliant, and deeply caring man. Every human and every robot now exploring the planets owes a debt to Murray. We were enriched by having known the man; the world of science and exploration is so much poorer for his loss.

— Excerpted from text courtesy of Louis D. Friedman and Charlene Anderson, The Planetary Society

W. S. B. Patterson, 1924–2013



W. S. B. Patterson.
Credit: David Fisher.

The terrestrial glaciology and planetary science communities suffered a great loss when glaciologist W. S. B. (Stan) Patterson died at the age of 89. Patterson perhaps best known for having authored the book *The Physics of Glaciers*, which has been the standard text in glaciology at most universities for more than four decades.

Patterson, who graduated with honors from the University of Edinburgh in 1949, became interested in glaciology when he was selected as a member of the British North Greenland Expedition (1953–1954). His survey of 300 points along a 1200-km-long traverse of the ice sheet proved incredibly accurate, with a closure error of just a few tens of centimeters.

In 1957, Patterson immigrated to Canada, entering the Ph.D. program in physics at the University of British Columbia (UBC). Patterson's research at UBC focused on the geometry, flow, and thermal properties of the Athabasca Glacier. After receiving his Ph.D. in 1962, he was hired as a glaciologist for Canada's newly-formed "Polar Continental Shelf Project" to survey and conduct research related to the country's vast and poorly mapped Arctic territories. Over the next several decades, he conducted drilling and GPR investigations of a number of glaciers ice caps in Canada's High Arctic. The data he and his team acquired have provided invaluable insights into the age, internal temperature, and mass balance of ice these glaciers and ice sheets, especially in recent times. This data has contributed to our understanding of climate change and have played a key role in establishing its reality and supporting the findings of the Intergovernmental Panel on Climate Change.

Patterson forged close links with international colleagues in the growing field of ice core research, especially in Denmark. By the early 1990s, his work was also being widely applied in the field of planetary science, particularly with respect to the evolution of the martian polar ice caps and the ice shelves of Europa. In November 1992 he served as a co-convener of the NASA/LPI Workshop on the

Polar Regions of Mars: Geology, Glaciology, and Climate History, a meeting that inspired many further collaborations between terrestrial glaciologists and planetary scientists — including the five highly successful International Conferences on Mars Polar Science and Exploration and the participation of a terrestrial glaciologist on NASA's ill-fated 1998 Mars Polar Lander and highly-successful 2008 Mars Phoenix Polar Lander missions.

In 2012, Patterson was awarded the Richardson Medal by the International Glaciological Society for his outstanding contributions to the field. In the words of his colleague and fellow glaciologist David Fisher, "Stan was one of those Scots who taught, mentored, and never hesitated to speak his mind" — a legacy that has earned Patterson a lasting legacy in terrestrial glaciology and planetary science.

— Text courtesy of Stephen Clifford and David Fisher

Gary B. Hansen, 1953–2013

Dr. Gary B. Hansen passed away late in the evening of September 26 from complications of ALS. He died while sitting at his computer, working on some science or technical issue. This was an apropos setting, as Hansen was a hard working and dedicated scientist who contributed to many aspects of the planetary sciences. He loved the work and the science, and working is what he most loved to do.

Hansen was born on July 12, 1953, in Denver, Colorado. He earned a B.S. in Engineering and Applied Science in 1975 from the California Institute of Technology, and earned an M.S. in Aeronautics and Astronautics (1986) and a Ph.D. in Geophysics (1996) from the University of Washington. He held a variety of positions throughout his career, beginning as an engineer for CBS television in Los Angeles from 1976 to 1979, then moving to Jet Propulsion Laboratory in Pasadena, California, as assistant cognizant engineer for the Galileo spacecraft flight computer. While at JPL he also performed considerable laboratory work on the properties of CO_2 ice, which eventually supported his Ph.D. dissertation. In 1996, he went to work with Tom McCord at the University of Hawaii as a researcher in the Division of Planetary Geosciences, and worked closely with McCord and his graduate students for six years before McCord retired from the university and established his own institute near Winthrop, Washington. Hansen then moved to the University of Washington and became a member of the research faculty there, but continued to work with McCord on joint projects.

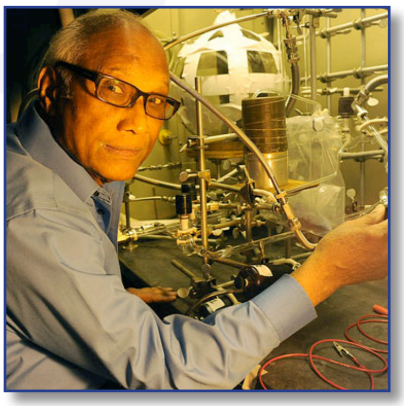
Hansen had a long connection with and loved Seattle, and he participated in its music and sports scenes as well as his research. He owned a house there even when he worked at the University of Hawaii. The University of Washington was the natural place for him to be located, and the Department of Earth and Space Science (ESS) found a way to enable this. Hansen contributed to various research efforts of the department and the university as a whole, in addition to continuing work on his own planetary science projects. As his health failed, the ESS provided what assistance and support they could to enable his participation until the end.

Hansen's specialty became radiative transfer, especially in multiscattering media, such as CO_2 and H_2O ices, and this was essential to the study of the outer solar system satellites. During the observational phase of the Galileo mission and its infrared spectrometer, NIMS, Hansen's deep understanding of the physics behind the signals the spectrometer was receiving contributed to several important discoveries regarding the spectral observations. Furthermore, Hansen was a wizard at developing calibrations and corrections for the finicky instrument and its idiosyncrasies, and he worked long, hard hours developing credibility for the NIMS data (and later for the VIMS data as well).

Hansen was an essential component of the growth and development of several graduate students and postdoctoral fellows, several of whom are professional scientists in their own right today, and they will surely join us in recognizing Hansen for his many contributions and friendship.

— Text courtesy of Tom McCord

Bishun N. Khare, 1933–2013



Bishun Khare, who studied the manner in which planets and moons naturally build up organic molecules in their atmospheres, died quietly on August 20 at the age of 80.

A research scientist at the SETI Institute who worked at NASA's Ames Research Center, Khare was also an adjunct professor of physics at San Jose State University. In the course of his career, he investigated the formation of compounds that make up the thick haze shrouding Saturn's moon Titan, as well as the methane and other organic compounds in the geysers that erupt from its sister moon, Enceladus. Many of these compounds were brought into being via photochemical reactions, in which energy from sunlight interacts with the natal gases of a planet or moon.

These processes are of as much interest to the biologist as to the chemist, for they could be important precursors to life. Khare's interest in biology-relevant chemistry dates to his work with astronomer Carl Sagan in the early 1970s. The two of them followed up an experiment performed at the University of Chicago two decades earlier, in which water and atmospheric gases were "cooked" by artificial lightning into amino acids — a result that seemed to show a natural pathway for the emergence of life on Earth. Khare and Sagan refined the Chicago experiment by using an updated mix of atmospheric gases — a better analog for the air that is thought to have blanketed the young Earth. Their effort confirmed that amino acids could be easily formed in the primitive terrestrial atmosphere of four billion years ago.

Khare's work in understanding the principal molecular component of Titan's haze — tholin — adopted a similar approach. Sparks and ultraviolet light provided the energy to create tholin in a laboratory mix of gases designed to be an analog of the Titan atmosphere. Khare then measured the spectral "fingerprint" of this material over a very broad range of wavelengths, from microwave to X-ray. This widely cited work has been of tremendous significance for studying other solar system bodies at a distance. Khare also took an interest in the properties of carbon nanotubes, a high-tech material that he envisioned will find increased use in space exploration. He had several patents in this area.

Born in Varanasi (also known as Banares), India, Khare earned degrees in physics, chemistry, and mathematics from Banaras Hindu University. His doctorate in physics was from Syracuse University, and he did postdoctoral research at both the State University of New York (Stony Brook) and at the University of Toronto. From the 1960s to the 1990s, he worked at Cornell University, and published approximately 100 papers with Carl Sagan. In 1996, he moved to NASA Ames as a Senior National Research Fellow, and in 1998 joined the SETI Institute.

Khare was enthusiastic and passionate about his work, but was also universally lauded for his gentle manner and extraordinary kindness. He leaves behind a remarkable legacy of exceptional competency and singular decency.

— Text courtesy of the SETI Institute

Feodor Velichko, 1957–2013

Feodor Velichko, a Leading Researcher of the Institute of Astronomy of Kharkiv National University in Ukraine, died suddenly on October 1 at the age of 56. Velichko was an expert in photometry and polarimetry of asteroids and comets and took part in many international observing programs devoted to physical studies of small bodies.

Velichko earned a Ph.S. in Physics and Mathematics Science in 1991 from the Main Astronomical Observatory of the Ukrainian National Academy of Science. Prior to his position at Kharkov, he served as the Director of the Chuguev Observing Station. He was a member of the Ukrainian Astronomical Society and the European Astronomical Society.

In addition to his work on the photometry, polarimetry, and spectrophotometry of visible and near-IR spectral regions of asteroids, comets, variable stars, planets and satellites, and artificial satellites, Velichko also conducted research on the determination and analysis of asteroid rotation parameters and binarity of asteroid systems.

— Portions of text courtesy of Irina Belskaya and the Division of Planetary Sciences

LPI Announces the 2013 Shoemaker Impact Cratering Award Recipient

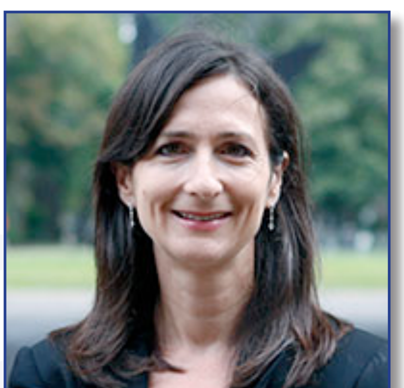
Michael Zanetti

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2013 recipient of the Eugene M. Shoemaker Impact Cratering Award is Michael Zanetti of Washington University in St. Louis. Zanetti is pursuing a Ph.D. with a heavy emphasis on lunar science and impact cratering processes at Washington University in St. Louis. He is working with Brad Jolliff. With funds provided with the GSA Planetary Geology Division's Eugene M. Shoemaker Impact Cratering Award, Zanetti will be studying zircon entrained in Mistastin crater impact melts.

The Eugene M. Shoemaker Impact Cratering Award is designed to support undergraduate and graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. Grants support the study of impact cratering processes on Earth and other bodies in the solar system, including asteroids and comets that produce impacts and the geological, chemical, or biological results of impact cratering.

This award is generously provided by the Planetary Geology Division of the Geological Society of America and administered by the LPI. It commemorates the work of Eugene ("Gene") Shoemaker, who greatly influenced planetary sciences during the Apollo era and for several decades thereafter, including the discovery of Comet Shoemaker-Levy 9 with his wife Carolyn and colleague David Levy.

Proposals for next year's award will be due in September 2014. Applications will be accepted beginning in late summer of 2014. Application details and a list of previous winners can be found at *www.lpi.usra.edu/Awards/shoemaker.*



Seager Named to 2013 Class of MacArthur Fellows

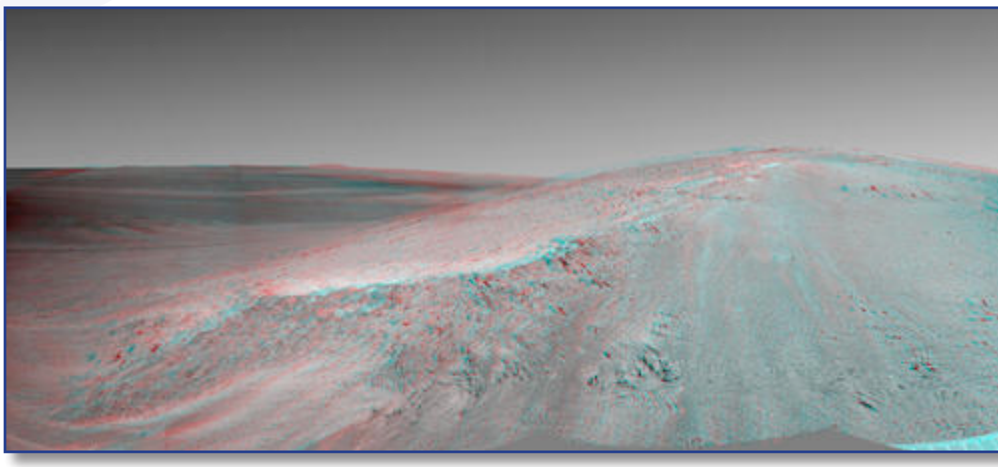
Sara Seager, astrophysicist and professor of planetary science and physics at the Massachusetts Institute of Technology, was named to the 2013 class of MacArthur Fellows. She is the editor of the *Exoplanets*, a volume in the prestigious Space Science Series published by the University of Arizona Press in collaboration with the Lunar and Planetary Institute.

MacArthur Fellows recognize exceptionally creative individuals with a track record of achievement and the potential for even more significant contributions in the future. Fellows receive a no-strings-attached stipend of $625,000 paid out over five years. Without stipulations or reporting requirements, the Fellowship provides maximum freedom for recipients to follow their own creative vision.

Seager is an astrophysicist and planetary scientist exploring the possibility of life throughout the galaxy. Adapting the principles of existing planetary science to the study of exoplanets (planets outside the solar system), she is quickly advancing a subfield initially viewed with skepticism by the scientific community. A mere hypothesis until the mid-1990s, nearly 900 exoplanets in more than 600 planetary systems have since been identified, with thousands more planet candidates known.

Early in her career, Seager determined that the nature of an exoplanet's atmosphere could be observed during an eclipse, when the planet's atmospheric light spectrum is especially distinct from its much brighter host star. She then envisioned and formalized a comprehensive framework for guiding and interpreting observations of planets in this manner, including parameters for calculating planet density and remotely detecting biosignature gases (spectroscopic signatures of chemical compounds that are indicative of life) in their atmospheric spectra. Her early predictions led to the first detection of an exoplanet atmosphere by observations from the Hubble Space Telescope. While continuing to create and refine theoretical models of exoplanet atmospheres and interiors, she is also spearheading advanced hardware design and space mission projects, including ExoplanetSat, a university collaboration to build low-cost "nano-satellites" to observe planetary transits. ExoplanetSat is a new concept for space science: a fleet of dozens of cheap copies of an ultrasmall space telescope that will open up a new avenue for wide-ranging space exploration. A visionary scientist contributing importantly in every aspect of her field, Seager is finding new celestial frontiers and fueling curiosity about life in worlds beyond our reach.

Mars Rover Teams Dub Sites In Memory of Bruce Murray



"Murray Ridge" in stereo from the Mars rover Opportunity. Credit: NASA/JPL-Caltech.

Features on Mars important to the missions of NASA's two active Mars rovers are now called "Murray Ridge" and "Murray Buttes," in honor of influential planetary scientist Bruce Murray (see related article in the "In Memoriam" section of this issue). The rover Opportunity, which has been roaming Mars for nearly a decade, is currently climbing Murray Ridge, part of an uplifted crater rim. NASA's newer rover, Curiosity, is headed toward Murray Buttes as the entryway to that mission's main destination.

"Bruce Murray contributed both scientific insight and leadership that laid the groundwork for interplanetary missions such as robotic missions to Mars, including the Mars rovers, part of America's inspirational accomplishments. It is fitting that the rover teams have chosen his name for significant landmarks on their expeditions," said NASA Mars Exploration Program Manager Fuk Li, of NASA's Jet Propulsion Laboratory (JPL).

Murray, a California Institute of Technology (Caltech) planetary geologist, worked on science teams of NASA's earliest missions to Mars in the 1960s and 1970s. He was the director of JPL from 1976 to 1982, then returned to teaching and research at Caltech. He co-founded the Planetary Society in 1980 and vigorously promoted public support for planetary exploration missions.

NASA's Mars Exploration Rover Opportunity, which has been working on Mars since 2004, has been investigating sites on the western rim of a 14-mile-wide (22-kilometer-wide) crater, Endeavour, for the past two years. The feature, informally named Murray Ridge, is an uplifted portion of the rim, a spine rising southward from "Solander Point" to an elevation about 130 feet (40 meters) above the surrounding plain.

"Murray Ridge is the highest hill we've ever tried to climb with Opportunity," said the mission's principal investigator, Steve Squyres of Cornell University in Ithaca, New York. The ridge has outcrops with clay minerals detected from orbit. It also provides a favorable slope for martian winter sunshine to hit the rover's solar panels, an advantage for keeping Opportunity mobile through the winter.

"Bruce Murray is best known for having been the director of JPL, and JPL is where our rovers were built," Squyres said. "He led JPL during a time when the planetary exploration budget was under pressure and the future for planetary missions was not clear. His leadership brought us through that period with a strong exploration program. He was also a towering figure in Mars research. His papers are still cited abundantly today."

The Curiosity rover is driving from a flatter area where it worked for several months after landing in 2012 to the slopes of a mountain 3 miles (5 kilometers) high, Mount Sharp. Murray Buttes, at the base of the mountain, are a cluster of small, steep-sided knobs, up to about the size of a football field and the height of a goal post. They sit in a gap in a band of dark sand dunes that lie at the foot of the mountain. Deep sand could present a hazard for driving, so this break in the dunes is the access path to the mountain.

"We'll be going right by these buttes when we shoot the gap in the dunes," said Curiosity science-team member Ken Herkenhoff, of the U.S. Geological Survey's Astrogeology Center in Flagstaff, Arizona. "It will be a visually intriguing area for both the science team and the public. I think it will look like a miniature version of Monument Valley in Utah."

Blowing sand from the dunes may scour dust off the buttes, exposing layers of rock for observation by the rover. Herkenhoff, who was a graduate student of Murray's in the 1980s, said, "Bruce Murray was a sedimentologist, so the sedimentary rocks we expect to see at Murray Buttes would have been especially interesting for him. He would have loved this."

Curiosity's science team plans for Murray Buttes to serve as a corridor from which to launch the rover's climb onto Mount Sharp.

USRA Team Selected for NASA Solar System Exploration Research Virtual Institute

The Universities Space Research Association (USRA) is proud to announce NASA's recent selection of scientists from USRA's Lunar and Planetary Institute (LPI), the Johnson Space Center (JSC), Arecibo Observatory, and colleagues at six universities to be one of the eight initial teams in NASA's Solar System Exploration Research Virtual Institute (SSERVI). SSERVI is a new organization that expands the scope of the NASA Lunar Science Institute to one that includes near-Earth asteroids and the moons of Mars.

The LPI/JSC team is led by Dr. David A. Kring, Senior Staff Scientist at the LPI and the founding Principal Investigator of the Center for Lunar Science and Exploration. Under the auspices of SSERVI, the team will continue to integrate science and exploration activities in a coordinated study of the Moon and the asteroids that bombard the Earth-Moon system. Those studies will include observations of existing near-Earth asteroids, studies of past collisional events in the Earth-Moon system, and the collisional evolution of the asteroid belt that delivers those objects to near-Earth space. The team includes partners from the Southwest Research Institute, University of Arizona, University of Hawaii, University of Houston, University of Maryland, University of Notre Dame, University of Colorado, and American Museum of Natural History in the United States, plus several scientific collaborators in the international community.

At the core of the program is the LPI-JSC Center for Lunar Science and Exploration, which, in its first five years of operation, has published the results of more than 50 scientific studies, trained more than 150 students and postdoctoral researchers, conducted a major assessment of possible lunar landing sites, and participated in both lunar and near-Earth asteroid mission simulations.

"This is an incredibly exciting moment," said Kring. "Our team is ready to help NASA implement a science and exploration program that returns the nation, along with our international partners, to ancient planetary surface environments that offer unbounded clues about our origins and intriguing opportunities for sustained operations in deep space."

"We are very pleased to be a part of the Solar System Exploration Research Virtual Institute," said Eileen Stansbery, Director of Astromaterials Research and Exploration Science at JSC. "This team is poised to address important scientific questions for not only understanding the formation and evolution of our nearest neighbors but also providing the scientific and technical expertise necessary to influence stepping out into the solar system with future space missions."

SSERVI members include academic institutions, non-profit research institutes, private companies, NASA centers, and other government laboratories. The winning teams, which SSERVI will support for five years at a total amount of approximately $12 million per year, were selected from a pool of 32 proposals based on competitive peer-review evaluation.

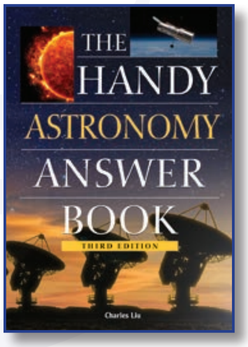
Other teams selected include the Institute for the Science of Exploration Targets: Origin, Evolution and Discovery (William Bottke, Southwest Research Institute in Boulder, Colorado); Center for Lunar and Asteroid Surface Science (Daniel Britt, University of Central Florida in Orlando, Florida); Volatiles, Regolith and Thermal Investigations Consortium for Exploration and Science (Ben Bussey, Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland); Dynamic Response of Environments at Asteroids, the Moon, and Moons of Mars (William Farrell, NASA Goddard Space Flight Center in Greenbelt, Maryland); Remote, In Situ and Synchrotron Studies for Science and Exploration (Timothy Glotch, Stony Brook University in New York); Field Investigations to Enable Solar System Science and Exploration (Jennifer Heldmann, NASA Ames Research Center in Moffett Field, California); Institute for Modeling Plasma, Atmospheres and Cosmic Dust (Mihaly Horanyi, University of Colorado in Boulder, Colorado); and Evolution and Environment of Exploration Destinations: Science and Engineering Synergism (Carle Pieters, Brown University in Providence, Rhode Island).

For more information about SSERVI, *visit sservi.nasa.gov*.

BOOKS

The Handy Astronomy Answer Book, Third Edition.

By Charles Liu. Visible Ink Press, 2013. 368 pp., Paperback, $21.95. *www.visibleinkpress.com*

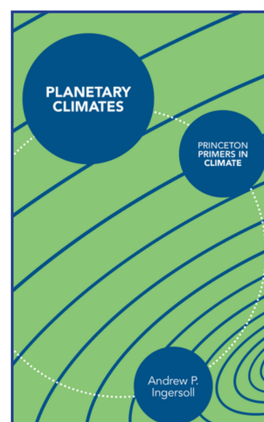


We look to the heavens and wonder in awe. Shooting stars, constellations, planets, galaxies, and the unknown. What is out there? Who is out there? How did the stars and planets come to be? What does it all mean? The last few years have brought an explosion of information leading to serious consideration of questions once deemed crazy. Do other universes exist? Are there planets that could harbor life? *The Handy Astronomy Answer Book* takes you on a journey through the history, science and the latest findings in astronomy. This book tells the story of astronomy — of the cosmos and its contents, and of humanity's efforts throughout history to unlock its secrets and solve its mysteries. You'll learn the answers to more than 1000 questions on astronomy and space, including What is astrobiology? What is the Dresden Codex, and what does it say about Mayan astronomy? What happened between Galileo and the Catholic Church? What is the longest time that a human has been in space? What is a gamma-ray burst? Where are the space shuttles today? How do I use a star chart to find stars and constellations? From the basic physics and history of astronomy to using star charts, telescopes, and other helpful hints for the home astronomer, and from space mission programs to the greatest adventure of all — the search for life beyond Earth — this book includes information on virtually every topic related to outer space. Containing over 120 color illustrations and photos, this book brings the wonders of our universe to life.

Planetary Climates.

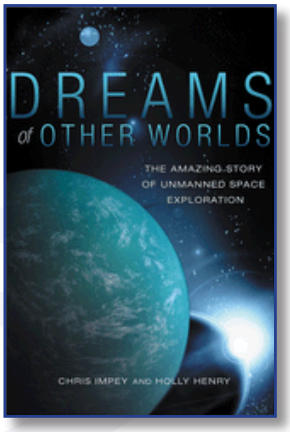
By Andrew P. Ingersoll. Princeton University Press, 2013. 288 pp., Paperback, $27.95. *press.princeton.edu*

This concise introduction to planetary climates explains the global physical and chemical processes that determine climate on any planet or major planetary satellite — from Mercury to Neptune and even large moons such as Saturn's Titan. Although the climates of other worlds are extremely diverse, the chemical and physical processes that shape their dynamics are the same. As this book makes clear, the better we can understand how various planetary climates formed and evolved, the better we can understand Earth's climate history and future. The book examines the wide-ranging planetary climates of our solar system, describing what planetary exploration has revealed and what is still unknown. Along the way, readers learn the fundamental equations that describe how climate processes work, including atmospheric escape, convection, radiative heat transfer, condensation and evaporation, and the dynamics of rotating fluids. The result is an ideal introduction for science students and nonspecialist scientists, as well as general readers with a scientific background.



Dreams of Other Worlds: The Amazing Story of Unmanned Space Exploration.

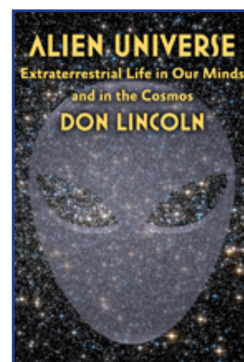
By Chris Impey and Holly Henry. Princeton University Press, 2013, 472 pp., Hardcover, $35.00. *press.princeton.edu*



Dreams of Other Worlds describes the unmanned space missions that have opened new windows on distant worlds. Spanning four decades of dramatic advances in astronomy and planetary science, this book tells the story of 11 iconic exploratory missions and how they have fundamentally transformed our scientific and cultural perspectives on the universe and our place in it. The journey begins with the Viking and Mars Exploration Rover missions to Mars, which paint a startling picture of a planet at the cusp of habitability. It then moves into the realm of the gas giants with the Voyager probes and Cassini's ongoing exploration of the moons of Saturn. The Stardust probe's dramatic round-trip encounter with a comet is brought vividly to life, as are the SOHO and Hipparcos missions to study the Sun and Milky Way. This book also explores how our view of the universe has been brought into sharp focus by NASA's great observatories — Spitzer, Chandra, and Hubble — and how the Wilkinson Microwave Anisotropy Probe mission has provided rare glimpses of the dawn of creation. *Dreams of Other Worlds* reveals how these unmanned exploratory missions have redefined what it means to be the temporary tenants of a small planet in a vast cosmos.

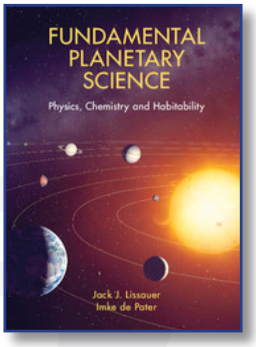
Alien Universe: Extraterrestrial Life in Our Minds and in the Cosmos.

By Don Lincoln. Johns Hopkins University Press, 2013, 216 pp., Hardcover, $29.95. *www.press.jhu.edu*



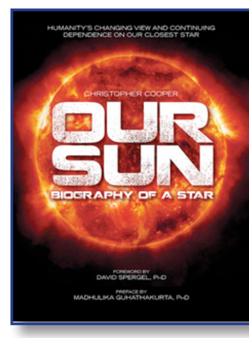
If extraterrestrials exist, where are they? What is the probability that somewhere out there in the universe an Earth-like planet supports an advanced culture? Why do so many people claim to have encountered aliens? Author and scientist Don Lincoln exposes and explains the truths about the belief in and the search for life on other planets. Lincoln looks to western civilization's collective image of aliens, showing how our perceptions of extraterrestrials have evolved over time. The roots of this belief can be traced as far back as our earliest recognition of other planets in the universe — the idea of them supporting life was a natural progression of thinking that has fascinated us ever since. Our captivation with aliens has, however, led to mixed results. The world was fooled in the nineteenth century during the Great Moon Hoax of 1835, and many people misunderstood, with calamitous results, Orson Welles' 1938 radio broadcast, *The War of the Worlds.* Our continuing interest in aliens is reflected in entertainment successes such as *E.T., The X-Files,* and *Star Trek.* He also explores the scientific possibility of whether advanced alien civilizations do exist. For many years, researchers have sought to answer Enrico Fermi's great paradox — if there are so many planets in the universe and there is a high probability that many of those can support life, then why have we not actually encountered any aliens? Whether you are drawn to the psychological belief in aliens, the history of our interest in life on other planets, or the scientific possibility of alien existence, this book will hold you spellbound.

Fundamental Planetary Science: Physics, Chemistry and Habitability.
By Jack J. Lissauer and Imke de Pater. Cambridge University Press, 2013, 616 pp., Paperback, $60.00.
www.cambridge.org



A quantitative introduction to the solar system and planetary systems science for advanced undergraduate students, this engaging new textbook explains the wide variety of physical, chemical, and geological processes that govern the motions and properties of planets. The authors provide an overview of our current knowledge and discuss some of the unanswered questions at the forefront of research in planetary science and astrobiology today. They combine knowledge of the solar system and the properties of extrasolar planets with astrophysical observations of ongoing star and planet formation, offering a comprehensive model for understanding the origin of planetary systems. The book concludes with an introduction to the fundamental properties of living organisms and the relationship that life has to its host planet. With more than 200 exercises to help students learn how to apply the concepts covered, this textbook is ideal for a one-semester or two-quarter course for undergraduate students.

Our Sun: Biography of a Star.
By Christopher Cooper. Race Point Publishing, 2013, 224 pp., Hardcover, $30.00. *www.racepointpub.com*



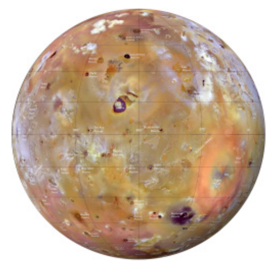
Our Sun is one star among 50 billion in the galaxy. Our galaxy is only one among 50 billion in the universe. With a vastness this incomprehensible, it is easy to feel like we are mere specks of sand on an endless shore. But our Sun is special. Although roughly 150 million kilometers separate us, we could not be more connected. Throughout our history, the Sun has been central to humanity's quest for meaning in the universe. But our history has been a brief moment in our Sun's 4.5-billion-year lifespan. Only recently, through advances in science and technology, have we begun to understand our Sun — where it came from, how it functions, how it affects our lives, and how it eventually will destroy our planet. *Our Sun* is a comprehensive, easy-to-understand guide to everything we know about our closest star. Illustrated with stunning pictures from NASA's newly-launched Solar Dynamics Observatory, *Our Sun* will reveal the science behind the Sun, trace its impact on human history, and reveal its growing importance to our future way of life.

GLOBES

Moon Globe — Kaguya.
Available from Blue Terra, 2013. Approximately $150 (contact company for details).
blue-terra.jp/blue-terra/index_e.html

The Japanese Moon explorer Kaguya brought us detailed information about the surface of the Moon. This Moon globe is based on classification by height. Three lava tubes discovered by Kaguya are labeled — they are considered potential locations for Moon bases. On the back side, highest and lowest points are indicated, and the six Apollo landing sites are labeled on the front. Feature names are given in both English and Japanese.

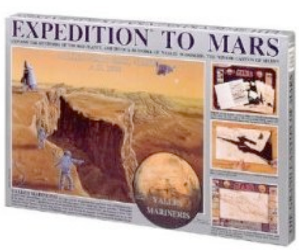
Galilean Moon Globes.
Available from Real World Globes. 10-inch unassembled, $125; 10-inch assembled, $150; 18-inch unassembled, $178; 18-inch assembled, $288. *www.realworldglobes.com*



Globes of the Galilean moons Callisto, Europa, Ganymede, and Io are now available in 10-inch, 18-inch, and 30-inch sizes with dry erase or matte finishes. The imagery of the moons includes the latest nomenclature and physiographic labels and each globe has a latitude and longitude grid. Each globe comes with a ring stand that enables easy viewing of the entire globe.

FOR KIDS!!!

Expedition to Mars 3-D Map Kit.
Produced by Edmund Scientifics. $5.99. Available from *amazon.com*

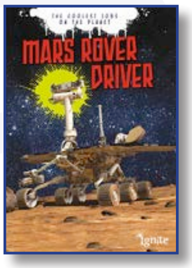


Explore the Red Planet and one of its most enigmatic features: Valles Marineris, the "Grand Canyon of Mars." This vast system of canyons stretches more than 2400 miles around Mars, up to 435 miles wide and 4.35 miles deep. On Earth it would traverse the entire North American continent from Los Angeles to New York. Arizona's Grand Canyon would be swallowed up by one of its minor side canyons. This Mars canyon was formed by tectonic forces, and scoured by ancient floods. Now you can explore its mysteries by building a 20" × 13" three-dimensional model of Valles Marineris. With this kit, you can assemble eight actual NASA contour maps compiled by a Mars-orbiting spacecraft, and mount them in a full-color frame with close-up views of the martian surface. Also included is 32-page instruction booklet. For ages 10 and up.

Space Exploration: It is Rocket Science!

By Simon Basher. Kingfisher, 2013. 64 pp., Paperback, $7.99. *us.macmillan.com*

Learn about the amazing research that is revolutionizing space exploration, from the pioneering spacecrafts and equipment known as "Space Aces" that have been used to delve into deep-space exploration, to the scientists known as "The Outerplanetary Mob" that have not only taken voyages to space and back but have contributed to our understanding of the universe. *Space Exploration* is a compelling guide to developments at the very forefront of science — a must-read for anyone wishing to understand, and engage with, modern space. For ages 8 to 12.



Mars Rover Driver.

By Scott Maxwell and Catherine Chambers. Raintree Publishing, 2014. 48 pp., Hardcover, $24.00. *www.capstonepub.com*

No one has yet visited Mars — at least, no humans have. Robot rovers have explored the surface of the Red Planet, and it's the job of people on Earth to control their every movement. Find out what's involved in being a rover driver, the tools and skills you need, and the difficulties of controlling something that's millions of miles away. For grades 5 to 8.

Glow-in-the-Dark Solar System Planetarium Model.

Produced by 4M. $40.00. Available from *amazon.com*

Build your own solar system planetarium model that spans almost 12 inches across. Assemble, paint, and highlight it with glow effects. Watch it glow in the dark as if in space. Kit contains a three-dimensional solar system planetarium model, strip of paint pots and glow paint, paint brush, a stand and rotating arms, eight steel bars, sand paper, a bonus wall chart of the solar system, and detailed instructions. For ages 8 and up.

Moon Games 2014 Wall Calendar.

Brush Dance Publishing, 2014. $14.95. *www.brushdance.com*

Capture the Moon in the palm of your hand as photographer Laurent Laveder playfully explores the night sky with his wildly popular Moon Games calendar. Measures 12" × 12".

Calendar 2014

January

5–9 **223rd Meeting of the American Astronomical Society,** Washington, DC. *https://aas.org/meetings/223rd-aas-meeting-washington-dc*

8–9 **Small Bodies Assessment Group Meeting,** Washington, DC. *http://www.lpi.usra.edu/sbag/*

10 **Ionising Processes in Atmospheric Environments of Planets, Brown Dwarfs, and M-Dwarfs,** London, United Kingdom. *http://www.ras.org.uk/component/gem/?id=250*

13–14 **Outer Planets Analysis Group (OPAG) Meeting,** Tucson, Arizona. *http://www.lpi.usra.edu/opag/*

13–16 **Fifth International Workshop on the Mars Atmosphere: Modelling and Observations,** Oxford, United Kingdom. *http://www-mars.lmd.jussieu.fr/oxford2014*

19–22 **Science with the Atacama Pathfinder Experiment (APEX),** Rottach-Egern, Germany. *https://indico.mpifr-bonn.mpg.de/indico/conferenceDisplay.py?confId=69*

20–24 **18th International Conference on Microlensing,** Santa Barbara, California. *http://lcogt.net/microlensing18*

February

3–4 **Vesta in the Light of Dawn: First Exploration of a Protoplanet in the Asteroid Belt,** Houston, Texas. *http://www.hou.usra.edu/meetings/vesta2014/*

3–6 **Exoplanet Observations with the E-ELT,** Garching, Germany. *http://www.eso.org/exoelt2014/*

5–7 **Workshop on the Habitability of Icy Worlds,** Pasadena, California. *http://www.hou.usra.edu/meetings/icyworlds2014/*

9–14 **Exoclimes III: The Diversity of Planetary Atmospheres,** Davos, Switzerland. *http://www.exoclimes.org/*

9–14 **AGU Chapman Conference on Magnetosphere-Ionosphere Coupling in the Solar System,** Yosemite National Park, California. *http://chapman.agu.org/magnetosphere/*

17–18 **First FISICA Workshop: Science Goals of a Sub-Arcsecond Far-Infrared Space Observatory,** Rome, Italy. *http://fisica.iaps.inaf.it/wp/*

18–19 **Science and Challenges of Lunar Sample Return Workshop,** Noordwijk, The Netherlands. *http://congrexprojects.com/2014-events/14c05/*

March

1–8 **IEEE Aerospace Conference,** Big Sky, Montana. *http://www.aeroconf.org/*

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*

20–22 **Meeting of the Astronomical Society of India 2014,** Mohali, India. *http://www.asi2014.in/*

April

1–3 **International Cometary Workshop,** Toulouse, France. *http://icw.space.swri.edu*

9–11 **International Workshop on Lunar Superconductor Applications (LSA),** Cocoa Beach, Florida. *http://lsaworkshops.com/*

22–24 **Humans to Mars Summit,** Washington, DC. *http://spaceref.com/calendar/calendar.html?pid=8221*

28–May 3 **21st Young Scientists' Conference on Astronomy and Space Physics,** Kiev, Ukraine. *http://ysc.kiev.ua/*

Calendar *continued . . .*

May

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*

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

June

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

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*

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

July

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/*

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

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–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*

August

2–10 **40th COSPAR Scientific Assembly,** Moscow, Russia. *http://www.cospar-assembly.org/*

4–8 **Cosmic Dust VII,** Osaka, Japan. *https://www.cps-jp.org/~dust/*

September

8–10 **Planet Formation and Evolution 2014,** Kiel, Germany. *http://www1.astrophysik.uni-kiel.de/~kiel2014/main/*

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*

October

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*

November

4–7 **International Workshop on Instrumentation for Planetary Missions,** Washington, DC. *http://ssed.gsfc.nasa.gov/IPM/*