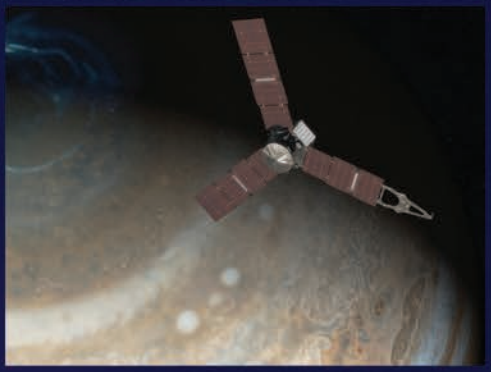
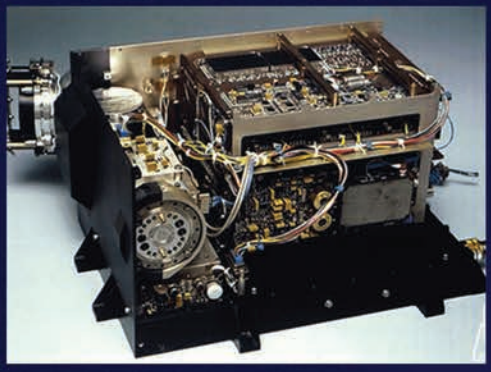
PLANETARY SCIENCE

AT THE SOUTHWEST RESEARCH INSTITUTE





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Lunar and Planetary Information

BULLETIN

Universities Space Research Association — Lunar and Planetary Institute

June 2014
Issue 137

www.lpi.usra.edu/lpib

Planetary Science at the Southwest Research Institute

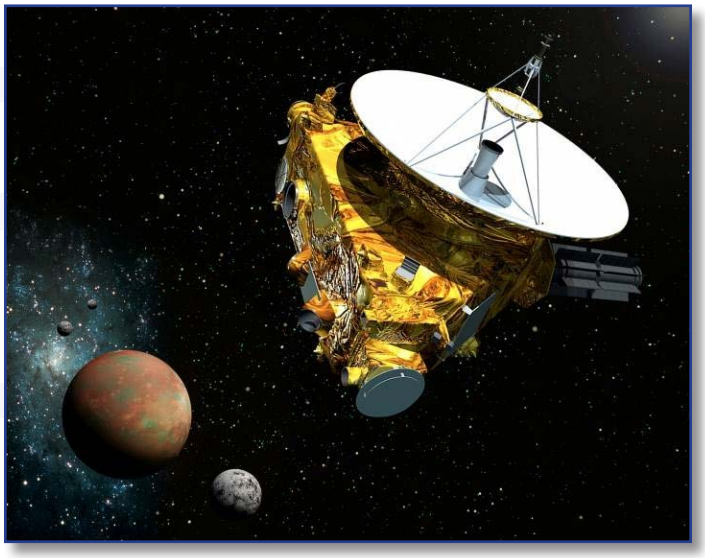
— Randy Gladstone, Southwest Research Institute

Note from the Editors: This issue's lead article is the third in a series of reports describing the history and current activities of the planetary research facilities funded by NASA and located nationwide. This issue features the Southwest Research Institute, which is one of the oldest and largest independent, nonprofit, applied research and development organizations in the United States, and which has made significant contributions to a number of planetary science missions. — Paul Schenk and Renee Dotson

The Southwest Research Institute (SwRI) was started in 1947 by visionary oilman Tom Slick as a nonprofit research facility. The main Institute consists of 11 divisions, covering about 1200 acres on the west side of San Antonio, Texas. Each division is actively engaged in a wide variety of challenging technical problems in areas such as engine research, fire technology, microencapsulation, robotics, and many others.

SwRI currently employs nearly 3000 people, and about 350 of these work in the Space Science and Engineering division, which opened in 1977 and in which most of the planetary science work at SwRI is performed. Planetary science research is conducted both at SwRI's main campus in San Antonio and at the Institute's Planetary Science Directorate in Boulder, Colorado, which opened in 1994. While heliophysics and space hardware is the primary focus in San Antonio, the Boulder office is primarily known for seminal research in planetary dynamics, solar physics, and outer solar system studies.

Although SwRI scientists contribute in a major way to NASA's research and analysis programs (with about 100 currently active NASA R&A projects), this article will concentrate on their involvement with planetary science missions and the design and development of the hardware on those missions. SwRI scientists are leading the first two of NASA's PI-led New Frontiers missions, the New Horizons mission to Pluto and the Kuiper belt and the Juno mission to Jupiter.



Artist's concept of the New Horizons spacecraft as it approaches Pluto and its three moons in summer 2015. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).

The New Horizons mission, led by Dr. Alan Stern (and built, managed, and operated by The Johns Hopkins University's Applied Physics Laboratory), will probe the geology and atmosphere of Pluto and its five known moons (including Charon), and then continue through the Kuiper belt, out of the solar system and into the galaxy beyond. New Horizons was launched in 2006 and investigated the jovian system during a Jupiter gravity assist in 2007. After more than eight years of cruising deep space, New Horizons is now on the final year of its long approach to the Pluto system, heading toward a flyby on July 14, 2015. Visible and near-infrared cameras on New Horizons

will map out the structure and composition of the frosty surface of Pluto in this last "first" exploration of one of the solar system's dwarf planets, changing it from a nearly unresolved blob to a unique, complex world in an instant of human history. Two instruments on New Horizons, the Alice ultraviolet spectrograph and the Solar Wind At Pluto (SWAP) particle spectrometer, were provided by SwRI. Alice will determine Pluto's atmospheric composition and structure by means of a solar occultation, and will also study Pluto's airglow emissions. SWAP will investigate the solar wind's interaction with Pluto's tenuous atmosphere, and provide an important constraint on the escape rate of its atmosphere.

The Juno spacecraft is shown in orbit above Jupiter's colorful clouds in this artist's rendering. Credit: NASA/JPL-Caltech.

The Juno mission, led by Dr. Scott Bolton (built by Lockheed Martin and managed by NASA's Jet Propulsion Laboratory), will in 2016 begin investigating the interior of Jupiter (i.e., core size, dynamo region, and oxygen abundance) as well as its polar magnetosphere. Juno was launched in 2011 and executed an Earth gravity assist last October, which put it on course to go into polar orbit at Jupiter on July 5, 2016. Juno will perform about 33 orbits before diving into Jupiter (planned to occur before the spacecraft sustains too much radiation damage). Each science orbit will be 11 days long. Most of the action on each orbit takes place during a few hours around perijove, as the spinning Juno spacecraft drops down over the north pole (from pre-dawn toward late afternoon), skims Jupiter's upper atmosphere at only a few thousand kilometers (about one-twentieth of Jupiter's radius) above the cloud tops, and then rises up and away again over the south pole. The very elongated polar orbit allows high-order measurements of the jovian gravity and magnetic fields (which contain the secrets of the interior structure), while avoiding the worst of Jupiter's killer radiation belts. As with New Horizons, SwRI provides two of Juno's instruments — the Ultraviolet Spectrograph (UVS) and the Jovian Auroral Distributions Experiment (JADE). While JADE measures local aurora-producing ions and electrons as they speed past Juno, UVS will watch as these particles light up Jupiter's atmosphere in auroras that are typically 1000 times brighter than those on Earth.

In addition to these prominent planetary science missions, SwRI leads several heliophysics missions as well, including the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), which observed the magnetosphere from high Earth orbit through remote sensing of photons and particles from 2000 to 2005, and the Magnetospheric Multiscale (MMS), an array of four satellites to be launched in early 2015 to investigate the physics of reconnection. Both of these missions were/are led by Dr. James Burch. Another heliophysics mission is the Interstellar Boundary Explorer (IBEX), led by Dr. Dave McComas, which since 2008 has, through observations of energetic neutral atoms, provided the first images of the complex boundary region where the solar wind encounters interstellar space.

SwRI scientists have also contributed instruments to a host of planetary missions. Historically, most of SwRI's efforts in instrument development for NASA were in the area of particle detectors and avionics. Over the past two decades, this has broadened to include cosmic-ray and ultraviolet instrumentation. Here we describe the most recent of these, grouped by the type of instrument.

Avionics —

SwRI has a long history of providing reliable flight computers and related electronics for a variety of NASA science missions, including those used on the IMAGE (heliophysics), Swift (astrophysics), Deep Impact (planetary), Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) (Earth), Kepler (astrophysics), and Wide-field Infrared Survey Explorer (WISE) (astrophysics) missions. Avionics developed by SwRI have flown on more than 60 space missions.

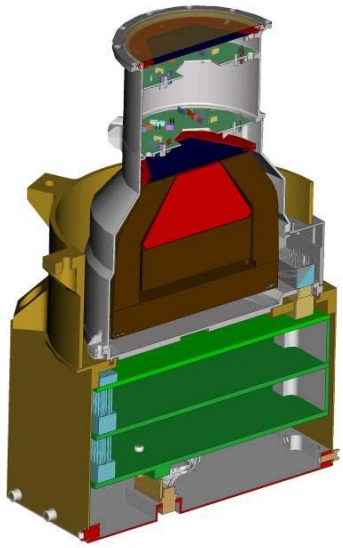
Particle Detectors and Mass Spectrometers —

SwRI scientists are in charge of the Cassini Plasma Spectrometer (CAPS), the development of which was led by SwRI, and Cassini's Ion and Neutral Mass Spectrometer (INMS), a facility instrument provided by NASA's Goddard Space Flight Center. These two Cassini instruments study the composition, dynamics, and temperature of plasmas and the composition of neutral material in the Saturn system, particularly around Saturn's largest moon, Titan. Because Titan and early Earth are thought to share many similarities, these studies could help us better understand Earth and solar system evolution. Using measurements from CAPS and INMS, SwRI scientists have obtained evidence that tholins, an organic material, are formed at high altitudes on Titan. Discovering a connection between tholins and massive negatively charged molecular ions and aerosols was completely unexpected. Similar organic chemistry occurs in galactic molecular clouds as well as during soot formation in Earth's troposphere and may have taken place in Earth's early atmosphere before the buildup of oxygen. In addition, INMS has sampled plumes emanating from the south polar region of the icy moon Enceladus, measurements that provide clues to the composition of the enceladan ocean and the geochemistry that occurs there.

As noted above, SwRI provided the SWAP and JADE particle instruments for New Horizons and Juno, respectively. The Strofio mass spectrometer will fly on the European Space Agency's (ESA) BepiColombo mission, which is currently scheduled for launch in 2016, and will be used to determine the composition of Mercury's atmosphere and surface. SwRI is also supporting particle suites on the upcoming Solar Probe Plus (NASA) and Solar Orbiter (ESA) missions to investigate the Sun and the workings of the inner heliosphere. In addition, SwRI designed and built the Ion and Electron Sensor (IES) for the ESA Rosetta mission, which will encounter Comet 67P/Churyumov-Gerasimenko in 2014.

Cosmic Rays (and Solar Energetic Particles) —

SwRI led the development of the Radiation Assessment Detector (RAD) for the Mars Science Laboratory rover mission, designed to characterize the radiation environment at the surface of Mars. The mission, part of NASA's Mars Exploration Program, is currently exploring the viability of the surface of the Red Planet as a potential habitat for past or present life. RAD has performed the first-ever measurements of cosmic rays and solar energetic particles on the surface of another planet and is busy characterizing the radiation environment to prepare for future human exploration of Mars.



About the size of a small toaster, the Radiation Assessment Detector on the Mars Science Laboratory looks skyward and uses a stack of silicon detectors and a crystal of cesium iodide to measure galactic cosmic rays and solar particles that pass through the martian atmosphere. Credit: NASA/JPL-Caltech/SwRI.

Ultraviolet Spectrographs —

SwRI has developed a series of ultraviolet spectrographs, beginning with the Alice instrument on ESA's Rosetta mission to Comet 67P/Churyumov-Gerasimenko and NASA's New Horizons mission to Pluto and the Kuiper belt (described above). Following these, the Lyman Alpha Mapping Project (LAMP) instrument was built for the Lunar Reconnaissance Orbiter (the first of the SwRI spectrographs to perform its primary mission, LAMP has been operating 24/7 in lunar orbit since September 2009). The UVS on Juno (mentioned earlier) is an updated version of the Alice design (with a faster detector and a scan mirror, among other changes), and the most recent spectrograph is currently being designed for ESA's Jupiter Icy Moon Explorer (JUICE) mission to Jupiter and Ganymede. These ultraviolet spectrographs can accomplish a variety of science, but mostly they excel at studying the tenuous interaction regions between the atmospheres of solar system bodies and the surrounding space environment.

Although considerably smaller than the major NASA centers and university-affiliated research centers such as APL, SwRI has demonstrated its ability to lead and support complex and challenging deep space missions. Even though SwRI may seem to have entered into the field of planetary science rather recently, it has a long history in space science research and exploration, and a busy future.

About the Cover—

Main image: *The main campus of the Southwest Research Institute covers approximately 1200 acres on the west side of San Antonio, Texas. Credit: SwRI.*

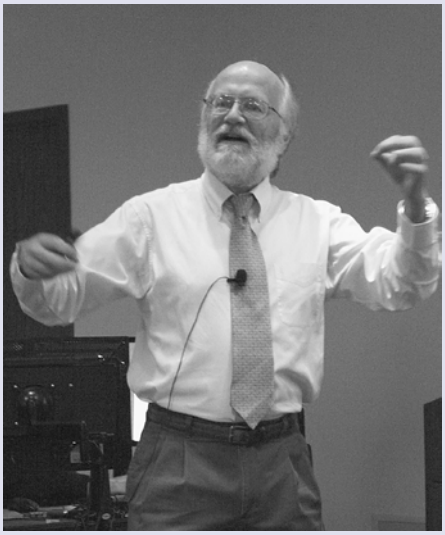
Inset, top left: *Artist's concept of the New Horizons spacecraft. Credit: JHUAPL/SwRI.*

Inset, bottom left: *This artist's concept depicts NASA's Juno spacecraft above Jupiter's north pole. Credit: NASA/JPL-Caltech.*

Inset, top right: *The ultraviolet imaging spectrograph on the New Horizons mission will be the first to study a comet up close. The shoebox-sized instrument is one-third to one-half the mass of comparable UV instruments, yet with more than 10,000 times as many imaging pixels as the spectrometer onboard Galileo. Credit: SwRI.*

Inset, bottom right: *The Ion and Neutral Mass Spectrometer (INMS) on the Cassini mission is collecting data to determine the composition and structure of positive ions and neutral particles in the upper atmosphere of Titan and the magnetosphere of Saturn. It is also measuring the positive ion and neutral environments of Saturn's rings and icy moons. Credit: NASA/JPL-Caltech.*

About the Author:



Dr. Randy Gladstone is an Institute Scientist for the Southwest Research Institute (SwRI) in San Antonio, Texas. He received his Ph.D. in planetary science in 1983 from the California Institute of Technology under advisor Yuk Yung. Prior to joining SwRI in 1993, he worked for the Space Sciences Laboratory at the University of California, Berkeley; the Laboratory for Atmospheric and Space Physics at Colorado University in Boulder; and York University, near Toronto, Canada.

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.

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Copy deadline for the next issue: August 15, 2014

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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.

Mission to Catch a Comet Approaches Its Target!

Comets have inspired awe and wonder since the dawn of history. Many scientists today believe that comets crashed into Earth during its formative period, spewing organic molecules that were crucial to the growth of life. Comets may have formed about the same time as the giant planets of our solar system (Jupiter, Saturn, Uranus, and Neptune) — about 4.6 billion years ago. It has been hypothesized that comets and planets were both made from the same clumps of dust and ice that spewed from our Sun's birth; alternatively, these roving time capsules may be even older than that, containing grains of interstellar stuff that is even older than our solar system!

This image of Rosetta in space shows its enormous solar arrays, stretching a total of nine feet across.

Rosetta is a spacecraft on a ten-year mission to catch Comet 67P/Churyumov-Gerasimenko (Comet 67P) and answer some of our questions about comets. Rosetta will be the first spacecraft to soft-land a robot on a comet. Rosetta will also be the first spacecraft to accompany a comet as it enters our inner solar system, observing at close range how the comet changes as the Sun's heat transforms it into the luminous apparition that has frightened and inspired people for centuries.

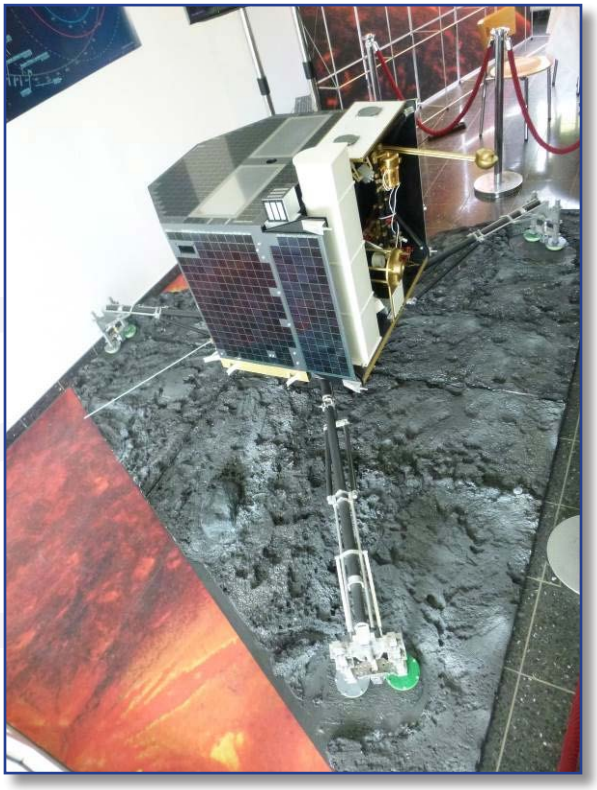


Photo of an engineering model of the "knee-high" Philae lander, taken by the editor (P.S.) May 2014.

The Rosetta spacecraft is named after the ancient Rosetta Stone, which you can see today in London's British Museum. The Philae lander is named after the Philae obelisk, which, together with the Rosetta Stone, provided the key to our first understanding of Egyptian hieroglyphs, or "picture words." Scientists hope that the Rosetta spacecraft will enable us to translate the even older language of comets, as expressed by their thermal signatures, into new knowledge about the origins of our solar system and perhaps life on Earth.

This daring international mission is spearheaded by the European Space Agency (ESA), with key support and instruments from NASA. NASA contributed three of the orbiter's instruments [an ultraviolet spectrometer known as Alice, the Microwave Instrument for the Rosetta Orbiter (MIRO), and the Ion and Electron Sensor (IES)] and part of the electronics package for the Double Focusing Mass Spectrometer — one of two detectors on the Swiss Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) instrument. NASA is also

providing science investigators for selected non-U.S. instruments. NASA's Deep Space Network provides support for ESA's Ground Station Network for spacecraft tracking and navigation.

Schedule of Events —

ESA's Science Programme Committee approved the International Rosetta Mission in November 1993 as a Cornerstone Mission in ESA's Horizons 2000 science program. On March 2, 2004, Rosetta was launched into an orbit that enabled it to chase Earth around the Sun for about a year. On March 4, 2005, Rosetta caught up with Earth and executed the first of its four gravity assists (three from Earth and one from Mars). This first gravity assist hurled Rosetta toward Mars for its meeting in 2007. En route to Mars, Rosetta's instruments analyzed the collision between Deep Impact's impactor and Comet Tempel-1 on July 4, 2005. In February 2007, Rosetta executed a close flyby of Mars, which provided the gravity assist it needed to loop back toward Earth for a second flyby in November 2007. In November 2007, Rosetta executed its second Earth flyby, gaining the gravity assist it needed to pass Mars' orbit and reach the asteroid belt. On September 5, 2008, Rosetta passed within 1700 kilometers of asteroid Steins, enabling its instruments to closely observe the flying rock. In November 2009, Rosetta swung back for a final boost from Earth's gravity to return again to the asteroid belt. On July 10, 2010, Rosetta flew within 3000 kilometers of asteroid Lutetia, and again used its instruments to observe at close range this asteroid, ten times larger than Steins. By May 2011, Rosetta was coasting through areas in the outer solar system where the Sun is almost a billion kilometers away. At that distance, Rosetta's solar panels are not able to gather much energy from the Sun, so the spacecraft shut down most electrical activities to hibernate until Comet 67P returns from its long transit in the outer solar system. After arrival, Rosetta will release the Philae lander for a controlled soft landing on the comet. Philae will use harpoons to anchor itself to the comet, and will then transmit critical data from the comet's surface for relay back to Earth.

ESA Head of Operations, Paolo Ferri (L), Rosetta mission manager Fred Jansen (R), and Rosetta spacecraft operations manager Sylvain Lodiot (seated) watch carefully as the May 21 "big burn" progressed. Credit: ESA.

The prime NASA contributions, ROSINA, Alice, MIRO, and IES, will provide information about the dynamics of Comet 67P: how it develops its coma and tails, and how its chemicals interact with each other and with radiation and the solar wind. Alice will map the comet's nucleus for pockets of both dust and ice. MIRO and ROSINA will examine the vicinity for signs of water coming off the nucleus; MIRO will do it remotely, and ROSINA will do it by waiting for particles to actually hit the detectors. IES will look for examples of direct interaction between the solar wind and the nucleus. Alice may also help scientists learn more about the origin of the comet and what its interstellar material can tell us about the origin of our solar system. While Alice and MIRO detect uncharged atoms and molecules, IES will detect

their charged counterparts — ions — as well as electrons. Both Alice and MIRO are remote sensing instruments that will be used to explore the comet's physical characteristics, including how its structure and composition change over time as it travels toward the Sun. In all, NASA is involved to a greater or lesser degree in many of the instruments on Rosetta and the experiments they will conduct: Alice; MIRO; IES; the Optical, Spectroscopic and Infrared Remote Imaging System (OSIRIS); radio science; ROSINA; and the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS).

Comet 67P on April 30, 2014. The comet — located just below the center of the image — already displays a coma. A globular cluster, M107, is clearly visible. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.

But before these experiments and measurements can take place, Rosetta must first get to the comet. After awaking from a three-year-long digital hibernation, in which nearly all its computer functions were turned off, Rosetta was prepared for a series of course adjustments in order to approach its target. The first major orbit correction maneuver (OCM) — or thruster burn — was completed as planned on April 22, providing the first of three big orbital "pushes" to get the spacecraft lined up for arrival in August. The burn ran for 7 hours and 16 minutes, one of the longest burns in ESA spaceflight history. The mission control team had live radio contact with the craft via ESA's New Norcia tracking station, and could follow progress in real time from a control room at the European Space Operations Centre (ESOC).

"[The May 21 maneuver] was absolutely necessary as part of a series of burns that will reduce Rosetta's speed with respect to the comet so that we arrive at 67P on August 6 with a relative speed of about 1 meter per second," said Sylvain Lodiot, Rosetta Spacecraft Operations Manager. The mission team watched closely as the burn was progressing, 500 million kilometers from Earth. "The thrusters and propulsion system overall performed very well, and we had a nominal completion of the burn at 22:39 UTC," says Lodiot. "It will take a few days for the flight dynamics team to analyze data and determine the final actual change in speed, but it won't be too far from what we planned." The OCM was programmed to deliver a relative change in speed with respect to Comet 67P of 291 meters per second. The burn used about 218 kilograms of fuel. Two more "big burns" were completed on June 4 and June 18; these will be followed by a series of six smaller burns until arrival at the comet (the two final "pre-orbit insertion" and "orbit insertion" burns are planned for August 3 and 6).

Meanwhile, the comet itself is showing that it cannot be ignored. The target of ESA's Rosetta mission has started to reveal its true personality as a comet, its dusty veil clearly developing over the past few months.

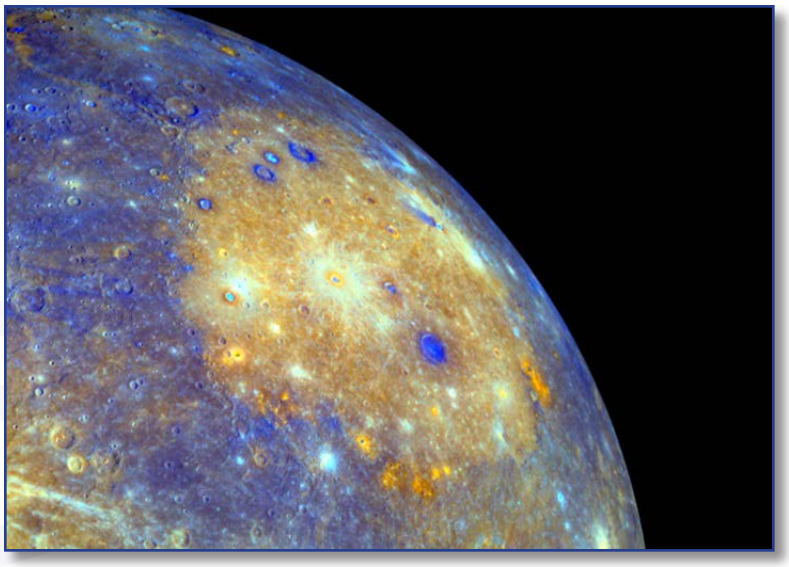
A sequence of images of Comet 67P were taken between March 27 and May 4, as the gap between craft and comet closed from around 5 million kilometers to 2 million kilometers.

By the end of the sequence, the comet's dusty veil — the "coma" — extends some 1300 kilometers into space. By comparison, the nucleus is roughly only 4 kilometers across, and cannot yet be resolved. The coma has developed as a result of the comet moving progressively closer to the Sun along its 6.5-year orbit. Even though it is still more than 600 million kilometers from the Sun — more than four times the distance between Earth and the Sun — its surface has already started to warm, causing its surface ices to sublimate and gas to escape from its rock-ice nucleus. As the gas escapes, it also carries a cloud of of tiny dust particles out into space, which slowly expands to create the coma. As the comet continues to move closer to the Sun, the warming continues and activity rises, and pressure from the solar wind will eventually cause some of the material to stream out into a long tail. Rosetta and the comet will be closest to the Sun in August 2015, between the orbits of Earth and Mars. The onset of activity now offers scientists the opportunity to study dust production and structures within the coma before getting much closer.

"It's beginning to look like a real comet," says Holger Sierks of the Max Planck Instute for Solar System Research, Germany, principal investigator for OSIRIS. "It's hard to believe that only a few months from now, Rosetta will be deep inside this cloud of dust and en route to the origin of the comet's activity." In addition, tracking the periodic changes in brightness reveals the nucleus is rotating every 12.4 hours — about 20 minutes shorter than previously thought. According to Lodiot, "These early observations are helping us to develop models of the comet that will be essential to help us navigate around it once we get closer."

OSIRIS and the spacecraft's dedicated navigation cameras have been regularly acquiring images to help determine Rosetta's exact trajectory relative to the comet. Using this information, the spacecraft has already started a series of maneuvers that will slowly bring it in line with the comet before making its rendezvous in the first week of August. Detailed scientific observations will then help to find the best location on the comet for the Philae lander's descent to the surface in November. "We have a challenging three months ahead of us as we navigate closer to the comet, but after a 10-year journey it's great to be able to say that our spacecraft is ready to conduct unique science at Comet 67P," says Fred Jansen, ESA's Rosetta mission manager.

For more information about the Rosetta mission, visit *rosetta.jpl.nasa.gov* or *www.esa.int/Our_Activities/Space_Science/Rosetta*.



This image of Mercury's Caloris Basin was taken before orbit insertion of the MESSENGER spacecraft. Credit: NASA.

MESSENGER Completes Its 3000th Orbit of Mercury

On April 20, the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft completed its 3000th orbit of Mercury and moved closer to the planet than any spacecraft has been before, dropping to an altitude of 199 kilometers (123.7 miles) above the planet's surface. "We are cutting through Mercury's magnetic field in a different geometry, and that has shed new light on the energetic electron population," said MESSENGER Project Scientist Ralph McNutt, of the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland. "In addition, we are now spending more time closer to the planet in general — and that has, in turn, increased the opportunities for all of the remote sensing instruments to make higher-resolution observations of the planet."

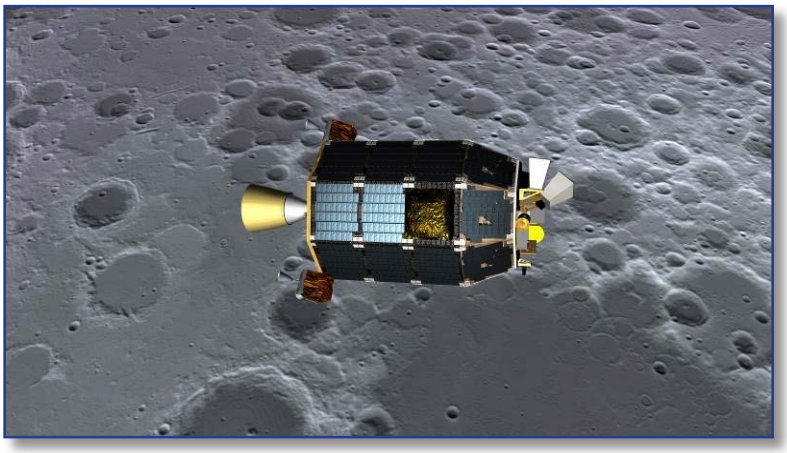
MESSENGER has been completing three orbits of Mercury every day since April 2012, when two orbit-correction maneuvers reduced its orbital period about Mercury from 12 hours to 8 hours. The shorter orbit has allowed the science team to explore new questions about Mercury's composition, geological evolution, and environment that were raised by discoveries made during the first year of orbital operations. APL's Carolyn Ernst, the deputy instrument scientist for the Mercury Laser Altimeter (MLA), said the change from a 12- to an 8-hour orbit provided her team with 50% more altimetry tracks. "MLA coverage takes a long time to build up, and because of the small footprint of the laser, a lot of coverage is needed to obtain good spatial resolution. The more data we acquire, the better we resolve the topography of the planet," she said. "The 8-hour orbit has also allowed us to make more MLA reflectivity measurements, which have provided critical clues for characterizing Mercury's radar-bright deposits at high northern latitudes."

The probe has been edging closer and closer to Mercury since March 2013, at about the time that the spacecraft orbit's minimum altitude passed closest to Mercury's north pole. APL's David Lawrence, a MESSENGER Participating Scientist, said he is excited about what the low-altitude orbits will reveal about Mercury's surface composition. "To date our compositional measurements with neutron, X-ray, and gamma-ray data have resolved only very large regions on Mercury's surface. Altitudes of less than 100 kilometers will enable us to pinpoint the compositional signatures of specific geologic features, which in turn will help us to understand how the surface formed and has changed over time."

MESSENGER's periapsis altitude continued to decrease until the first orbit-correction maneuver of the low-altitude campaign, which was scheduled for June 17. For more information, visit *messenger.jhuapl.edu*.

LADEE Mission Ends with Planned Impact on the Lunar Surface

NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft impacted the surface of the Moon, as planned, between 9:30 and 10:22 p.m. PDT on Thursday, April 17. LADEE lacked fuel to maintain a long-term lunar orbit or continue science operations and was intentionally sent into the lunar surface. The spacecraft's orbit naturally decayed following the mission's final low-altitude science phase. During impact, engineers believe the LADEE spacecraft, the size of a vending machine, broke apart, with most of the spacecraft's material heating up several hundred degrees — or even vaporizing — at the surface. Any material that remained is likely buried in shallow craters.



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

"At the time of impact, LADEE was traveling at a speed of 3600 miles per hour — about three times the speed of a high-powered rifle bullet," said Rick Elphic, LADEE project scientist at Ames. "There's nothing gentle about impact at these speeds — it's just a question of whether LADEE made a localized craterlet on a hillside or scattered debris across a flat area. It will be interesting to see what kind of feature LADEE has created."

In early April, the spacecraft was commanded to carry out maneuvers that would lower its closest approach to the lunar surface. The new orbit brought LADEE to altitudes below one mile (two kilometers) above the lunar surface. This is lower than most commercial airliners fly above Earth, enabling scientists to gather unprecedented science measurements. On April 11, LADEE performed a final maneuver to ensure a trajectory that caused the spacecraft to impact the farside of the Moon, which is not in view of Earth or near any previous lunar mission landings. LADEE also survived the total lunar eclipse on April 14–15. This demonstrated the spacecraft's ability to endure low temperatures and a drain on batteries as it, and the Moon, passed through Earth's deep shadow.

In the coming months, mission controllers will determine the exact time and location of LADEE's impact and work with the agency's Lunar Reconnaissance Orbiter (LRO) team to possibly capture an image of the impact site. Launched in June 2009, LRO provides data and detailed images of the lunar surface. "It's bittersweet knowing we have received the final transmission from the LADEE spacecraft after spending years building it in-house at Ames, and then being in constant contact as it circled the Moon for the last several months," said Butler Hine, LADEE project manager at Ames.

Launched in September 2013 from NASA's Wallops Flight Facility in Virginia, LADEE began orbiting the Moon on October 6 and gathering science data on November 10. The spacecraft entered its science orbit around the Moon's equator on November 20, and in March 2014, LADEE extended its mission operations following a highly successful 100-day primary science phase. LADEE also hosted NASA's first dedicated system for two-way communication using laser instead of radio waves. The Lunar Laser Communication Demonstration (LLCD) made history using a pulsed laser beam to transmit data over the

239,000 miles from the Moon to Earth at a record-breaking download rate of 622 megabits-per-second (Mbps). In addition, an error-free data upload rate of 20 Mbps was transmitted from the primary ground station in New Mexico to the Laser Communications Space Terminal onboard LADEE.

LADEE gathered detailed information about the structure and composition of the thin lunar atmosphere. In addition, scientists hope to use the data to address a long-standing question: Was lunar dust, electrically charged by sunlight, responsible for the pre-sunrise glow seen above the lunar horizon during several Apollo missions? A thorough understanding of the characteristics of our nearest celestial neighbor will help researchers understand other bodies in the solar system, such as large asteroids, Mercury, and the moons of outer planets.

For more information, visit *www.nasa.gov/ladee* and *llcd.gsfc.nasa.gov*.

New Radar Images Uncover Remarkable Features Below the Surface of the Moon

New images of Earth's Moon reveal more than can be seen with the naked eye, thanks to the combined efforts of the two largest radio telescopes of their kind — the National Radio Astronomy Observatory's Green Bank Telescope (GBT) in West Virginia and the Arecibo Observatory in Puerto Rico. To make these images, radar signals beamed from Arecibo's powerful transmitter penetrated deep below the Moon's dusty surface. The signals then rebounded back and were picked up by the sensitive receivers on the GBT. This observing technique, known as bistatic radar, has been used to study many objects in our solar system, including asteroids and other planets.

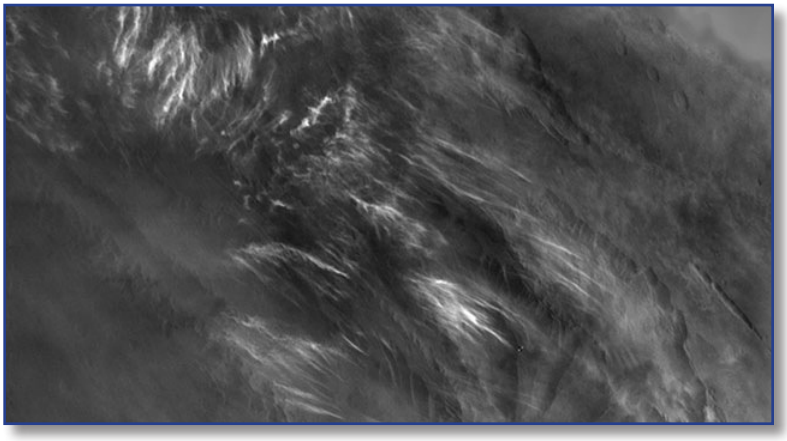
Mare Serenitatis/Sea of Serenity. Credit: Bruce Campbell (Smithsonian Institution, National Air and Space Museum); Arecibo/NAIC; NRAO/AUI/NSF.

The image shown here reveals previously hidden features around an area known as Mare Serenitatis, or the Sea of Serenity, which is near the Apollo 17 landing site. The radar observations were able to "see" approximately 10–15 meters (33–50 feet) below the lunar surface. The light and dark features are the result of compositional changes in the lunar dust and differences in the abundance of rocks buried within the soil. An additional image taken is a similar observation of the lunar impact crater known as Aristillus, in which radar echoes reveal geologic features of the large debris field created by the force of the impact.

These images help planetary scientists interpret the complex history of the Moon, which is often obscured by dust layers built up over billions of years, better understand the geology of earlier landing sites, and plan for future lunar exploration. For more information, visit *science.nrao.edu/facilities/gbt* and *www.naic.edu*.

NASA Moves Longest-Serving Mars Spacecraft for New Observations

NASA's Mars Odyssey spacecraft has tweaked its orbit to help scientists make the first systematic observations of how morning fogs, clouds, and surface frost develop in different seasons on the Red Planet. The maneuver took place on Tuesday, February 11. Odyssey team engineers at NASA's Jet Propulsion Laboratory (JPL) and Lockheed Martin Space Systems of Denver designed the gentle move to accelerate Odyssey's drift toward a morning-daylight orbit. The desired change will occur gradually until the intended orbit geometry is reached in November 2015 and another maneuver halts the drift.



No NASA Mars orbiter has been in a position to observe morning daylight on Mars since the twin Viking orbiters of the 1970s. Credit: NASA/JPL.

The change will enable observation of changing ground temperatures after sunrise and after sunset in thousands of places on Mars. Those observations could yield insight about the composition of the ground and about temperature-driven processes, such as warm-season flows observed on some slopes and geysers fed by spring thawing of carbon-dioxide ice near Mars' poles. "We're teaching an old spacecraft new tricks," said Odyssey Project Scientist Jeffrey Plaut of JPL. "Odyssey will be in position to see Mars in a different light than ever before." Neither Odyssey, nor any other NASA Mars orbiter since the 1970s, has flown an orbital pattern with a view of the ground in morning daylight. Earlier NASA orbiters and the European Space Agency's Mars Express orbiter have provided some tantalizing views of morning mists on Mars, but have concentrated on afternoon observation times when views of the surface are less hazy.

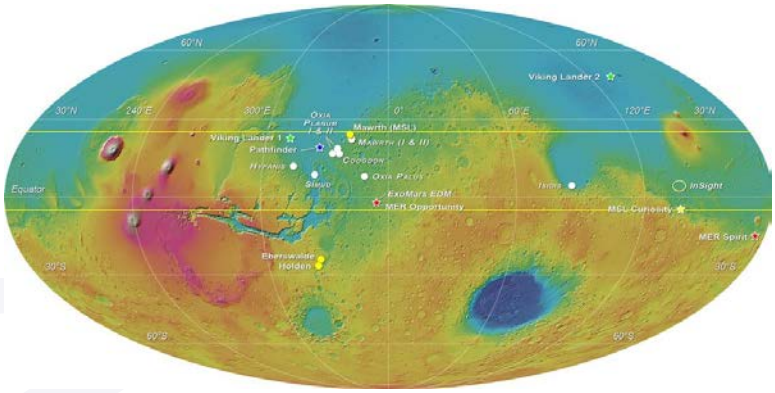
Odyssey was launched in 2001 and began its science mission 12 years ago. It is the longest-working spacecraft ever sent to Mars. Odyssey flies in an orbit nearly over the poles and synchronized with the Sun. For most of its first six years at Mars, the orbit was set at about 5:00 (local solar time). At every spot Odyssey flew over as it made its dozen daily passes from the north pole region to the south pole region, the local solar time was about 5:00 p.m. Beneath the south-to-north leg of the orbit, the time was about 5:00 a.m. That orbit provided an advantage for the orbiter's Gamma Ray Spectrometer to have its cooling equipment pointed away from the Sun. The spectrometer checked for evidence of water near the martian surface. It made important discoveries of how widely water ice — detected as hydrogen — and other elements are distributed on Mars.

Later, Odyssey worked for three years in a 4:00 orbit. That provided an advantage for mineral mapping by the orbiter's Thermal Emission Imaging System (THEMIS). Mid-afternoon warmth made the infrared signatures of minerals easier to identify. This timing, however, added stress to Odyssey's power system. It put more of each orbit into the planet's shadow, where solar panels are unproductive. After providing radio-relay support for the 2012 landing of NASA's Curiosity Mars rover, a maneuver set Odyssey on a slow drift to later times of day to help preserve the spacecraft's aging battery.

THEMIS Principal Investigator Philip Christensen of Arizona State University in Tempe proposed letting the time of the orbit shift past 6:00 and then making daylight observations on the south-to-north half of the orbit, at about 6:45 a.m., rather than the north-to-south half. The science team and NASA agreed, and the Odyssey project planned the February maneuver to get to the desired orbit sooner. "We don't know exactly what we're going to find when we get to an orbit where we see the morning just after sunrise," Christensen said. "We can look for seasonal differences. Are fogs more common in winter or spring? We will look systematically. We will observe clouds in visible light and check the temperature of the ground in infrared."

After the next orbit-adjustment maneuver, to lock into the 6:45 a.m. local time in November 2015, Odyssey will have about enough propellant left for 9 to 10 years of operation at estimated annual consumption rates. In addition to conducting its own observations, Odyssey serves as an important communications relay for spacecraft on Mars' surface. For more information, visit *mars.jpl.nasa.gov/odyssey*.

Scientists Favor Four ExoMars Landing Sites



MOLA elevation map of Mars with white circles showing the eight landing sites proposed for the ExoMars 2018 mission.

Some 60 scientists and engineers came together on March 26–28 for the first ExoMars 2018 Landing Site Selection Workshop, held at ESA's European Space Astronomy Centre near Madrid. Their task was to begin the process of drawing up a short list of the most suitable landing locations for ESA's first Mars rover. ExoMars, a joint endeavour between ESA and Russia's Roscosmos space agency, comprises two missions for launch to Mars: the Trace Gas Orbiter and an entry, descent, and landing demonstrator module, Schiaparelli, to be launched in 2016; and the ExoMars Rover and Surface Platform scheduled for launch in May 2018, with touchdown on Mars expected in January 2019. The key driver behind the choice of landing site for the 2018 mission is the rover's search for evidence of martian life, past or present. A call for landing site proposals was issued last year by ESA and the Space Research Institute of the Russian Academy of Sciences, IKI (on behalf of Roscosmos). Eight proposals that were judged to be most appropriate to the mission's requirements were discussed during the recent workshop, and an initial short list of four favored locations was drawn up at the end of the meeting.

Present-day Mars is a hostile place for living organisms — a frigid desert bathed in high doses of ultraviolet and ionizing radiation. However, there is a possibility that primitive life may have gained a foothold when the climate was warmer and wetter, between 3.5 and 4 billion years ago. Clearly, the ExoMars landing site should be an area of ancient rocks where liquid water was once abundant, preferably in a region that shows signs of sustained or frequently recurring aqueous activity, such as river channels and lakes.

On Earth, biosignatures can be found in fine-grained sedimentary rocks deposited by slow-moving water, for example, in alluvial plains or river deltas. Some of these rocks, such as clays, are very good at capturing and retaining organic compounds. Clay minerals are also evidence of sustained weathering by groundwater of low acidity. On the other hand, large doses of ionizing radiation on Mars sterilize the surface and penetrate the martian subsurface, contributing to the destruction of possible biosignatures. In order to find ancient biomarkers in a good state of preservation, the deposits containing them must have been buried for most of the planet's history and thus protected, until recently, from radiation damage. One further complication is the covering of fine dust that blankets much of Mars. The ExoMars rover will search for molecular biosignatures by drilling into the subsurface, collecting samples and then analyzing them in its onboard chemical laboratory. The vehicle can drill to a maximum depth of 2 meters, so the dust cover at each site should ideally be very thin or nonexistent.

Time is of the essence if the maximum scientific return from ExoMars is to be achieved. The rover can cover a limited driving range in the course of its seven-month nominal surface exploration mission. The spacecraft's ballistic entry into the atmosphere is a rather imprecise procedure, which means that it could land anywhere within a 104 kilometer × 19 kilometer ellipse. In order to ensure that the rover spends as much time as possible conducting scientific research, a landing ellipse should contain a scattering of suitable sites to ensure that at least some of them are accessible to the rover.

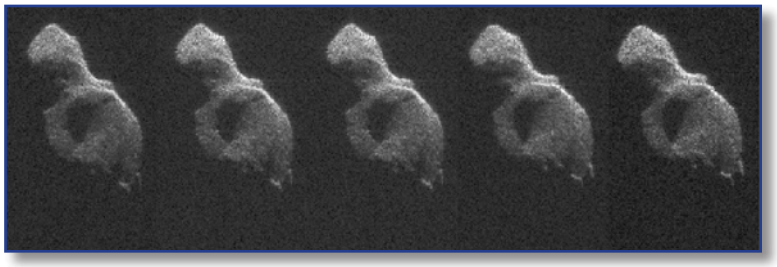
In addition to these scientific requirements, the use of parachutes to slow the spacecraft's descent restricts the landing sites that can be chosen. In particular, candidate sites must all lie at least 2 kilometers beneath the mean planetary reference level — the martian equivalent of sea level. This is to ensure that the spacecraft can fly through a sufficiently long atmospheric trajectory for its parachute system to operate properly. Other important engineering constraints include surface gradients, which if too steep could fool the descent module's radar, the size and distribution of rocks that may topple or damage the lander, and wind speed.

The workshop attendees favored four candidate sites — all of which are located relatively near the equator — that were considered to be the most likely to achieve the mission's objectives. They are Mawrth Vallis (for which two very similar proposals were received), Oxia Planum, Hypanis Vallis, and Oxia Palus. The area around Mawrth Vallis and nearby Oxia Planum contains one of the largest exposures of ancient, clay-rich rocks on the planet. Both regions contain rock types that may have been favorable for complex organic chemistry, and layered rocks that may preserve evidence of past life. Also, some of these deposits seem to have been exhumed within the last few hundred million years, thus reducing their exposure to radiation. The other two sites represent former fluvial environments. Hypanis Vallis is characterized by fine-grained sedimentary rocks associated with an ancient delta located at the end of a major valley network. Oxia Palus is a region of sedimentary rocks that was buried by impact ejecta and other deposits and has only been exhumed relatively recently.

Over the next few months, members of the ExoMars Landing Site Selection Working Group (LSSWG) will seek to improve their understanding of the scientific and engineering implications associated with each of these four locations, while also devoting some attention to the three remaining sites — Coogoon Valles, Simud Vallis, and Southern Isidis. The LSSWG will then recommend a final short list of up to four candidate sites, prior to a more detailed analysis. The aim is to complete the certification of at least one landing site for the ExoMars rover by the second half of 2016. The final decision on the landing site will be made sometime in 2017. For more information, visit *exploration.esa.int/mars/*.

High-Resolution Radar at Arecibo Observatory Reveals Asteroid As a Beauty, Not a Beast

Arecibo and NASA scientists using Earth-based radar have produced sharp views of a recently discovered asteroid as it slid safely past our planet. The new views of asteroid 2014 HQ124 are some of the most detailed images of a near-Earth asteroid ever obtained with Arecibo Observatory and Goldstone Solar System Radar (GSSR). The images were taken on June 8, when asteroid 2014 HQ124 safely passed Earth a little over three times the distance from Earth to the Moon (about 1.3 million kilometers or 800,000 miles). Arecibo Observatory, together with the GSSR, observed HQ124 nine hours after the closest approach. "These radar observations show that the asteroid is a beauty, not a beast," said Alessondra Springmann, a data analyst at Arecibo Observatory, noting the complex structure of the asteroid and its peanut shape visible in the radar data.



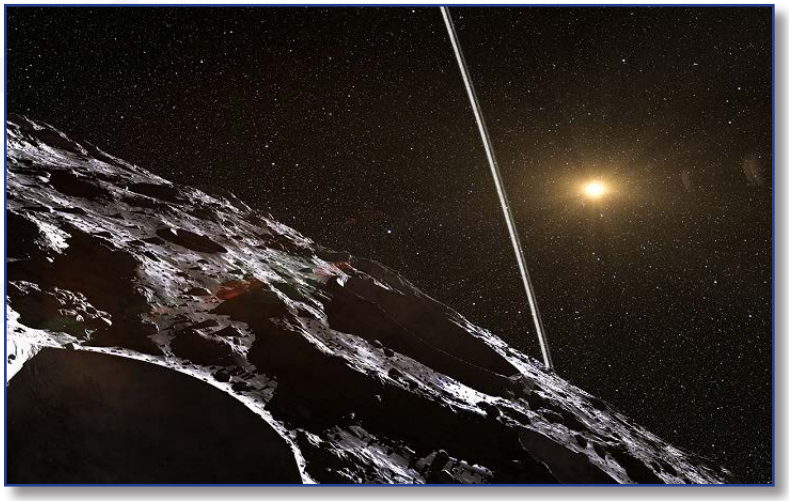
Radar images of 2014 HQ124 show an elongated asteroid with an irregular surface at least 370 meters (1200 feet) in size, slightly larger than the 305-meter (1000-foot) Arecibo Observatory dish. This asteroid spins on its axis in approximately 20 hours. Credit: Marina Brozovic and Joseph Jao, Jet Propulsion Laboratory/Caltech/NASA/USRA/ Arecibo Observatory/NSF.

Most radar experiments involve one radio telescope transmitting signal to the asteroid, then receiving reflected radio waves from the asteroid. Scientists observing asteroid 2014 HQ124 directed the 70-meter (230-foot) GSSR — also known as DSS-14 — to transmit to the asteroid, then the 305-meter (1000-foot) Arecibo Observatory collected the reflected waves. "We used two telescopes because that combination allowed us to get images with twice as much detail as Arecibo could achieve otherwise," said Lance Benner, a scientist at the Jet Propulsion Laboratory who led the radar observations at Goldstone.

Using this configuration — GSSR transmitting, Arecibo receiving — was made possible by newly installed hardware at Arecibo that allows it to combine the 3.75-meter resolution of the GSSR transmitter with the unmatched sensitivity of the 305-meter Arecibo telescope, providing the first high-resolution radar images of an asteroid with this level of clarity from any radar system. Arecibo and GSSR scientists hope to use this new system regularly for studying near-Earth asteroids. For more information, visit *www.naic.edu* or *gssr.jpl.nasa.gov*.

First Ring System Around Asteroid: Chariklo Found to Have Two Rings

Observations at many sites in South America, including the European Southern Observatory's (ESO) La Silla Observatory in Chile, have made the surprise discovery that the remote asteroid Chariklo is surrounded by two dense and narrow rings. This is the smallest object by far found to have rings and only the fifth body in the solar system — after the much larger planets Jupiter, Saturn, Uranus, and Neptune — to have this feature. The origin of these rings remains a mystery, but they may be the result of a collision that created a disc of debris. The new results were published online in the journal *Nature* on March 26.



This artist's impression shows how the rings might look from close to the surface of Chariklo. Credit: ESO/L. Calçada/Nick Risinger.

The rings of Saturn are one of the most spectacular sights in the sky, and less-prominent rings have also been found around the other giant planets. Despite many careful searches, no rings had been found around smaller objects orbiting the Sun in the solar system. Now observations of the distant minor planet (10199) Chariklo as it passed in front of a star have shown that this object too is surrounded by two fine rings. "We weren't looking for a ring and didn't think small bodies like Chariklo had them at all, so the discovery — and the amazing amount of detail we saw in the system — came as a complete surprise!" said Felipe Braga-Ribas of the Observatório Nacional/MCTI in Rio de Janeiro, Brazil, who planned the observation campaign and is the lead author of the paper.

Chariklo is the largest member of a class known as the Centaurs, and it orbits between Saturn and Uranus in the outer solar system. Predictions had shown that it would pass in front of the star UCAC4 248-108672 on June 3, 2013, as seen from South America. Astronomers using telescopes at seven different locations, including the 1.54-meter Danish and TRAPPIST telescopes at La Silla Observatory, were able to watch the star apparently vanish for a few seconds as its light was blocked by Chariklo — an occultation. But they found much more than they were expecting. A few seconds before, and again a few seconds after the main occultation, there were two further very short dips in the star's apparent brightness. Something around Chariklo was blocking the light! By comparing what was seen from different sites the team could reconstruct not only the shape and size of the object itself but also the shape, width, orientation, and other properties of the newly discovered rings.

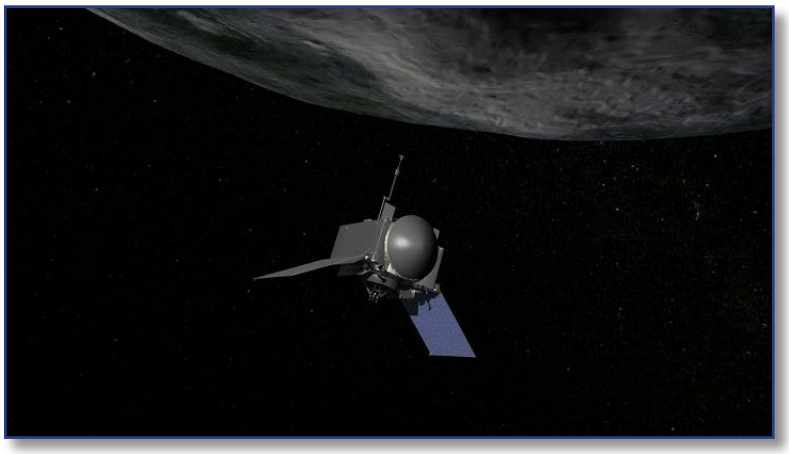
The team found that the ring system consists of two sharply confined rings only seven and three kilometers wide, separated by a clear gap of nine kilometers — around a small 250-kilometer-diameter object orbiting beyond Saturn. "For me, it was quite amazing to realize that we were able not only to detect a ring system, but also pinpoint that it consists of two clearly distinct rings," added Uffe Gråe Jørgensen of the Niels Bohr Institute, University of Copenhagen, Denmark, one of the team members.

"I try to imagine how it would be to stand on the surface of this icy object — small enough that a fast sports car could reach escape velocity and drive off into space — and stare up at a 20-kilometer-wide ring system 1000 times closer than the Moon."

Although many questions remain unanswered, astronomers think that this sort of ring is likely to be formed from debris left over after a collision. It must be confined into the two narrow rings by the presence of small putative satellites. The rings may prove to be a phenomenon that might in turn later lead to the formation of a small moon. Such a sequence of events, on a much larger scale, may explain the birth of our own Moon in the early days of the solar system, as well as the origin of many other satellites around planets and asteroids.

The leaders of this project are provisionally calling the rings by the nicknames Oiapoque and Chuí, two rivers near the northern and southern extremes of Brazil. For more information, visit *www.eso.org*.

Construction to Begin on NASA Spacecraft Set to Visit Asteroid in 2018



Artist's concept of NASA's OSIRIS-REx spacecraft preparing to take a sample from asteroid Bennu. Credit: NASA/Goddard.

NASA's team that will conduct the first U.S. mission to collect samples from an asteroid has been given the go-ahead to begin building the spacecraft, flight instruments and ground system, and launch support facilities. This determination was made on April 10 after a successful Mission Critical Design Review (CDR) for NASA's Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx). The CDR was held at Lockheed Martin Space Systems Company in Littleton, Colorado, on April 1–9. An independent review board, comprising experts from NASA and several external organizations, met to review the system design. "This is the final step for a NASA mission to go from paper to product," said Gordon Johnston, OSIRIS-REx program executive at NASA Headquarters in Washington, DC. "This confirms that the final design is ready to start the build-up towards launch."

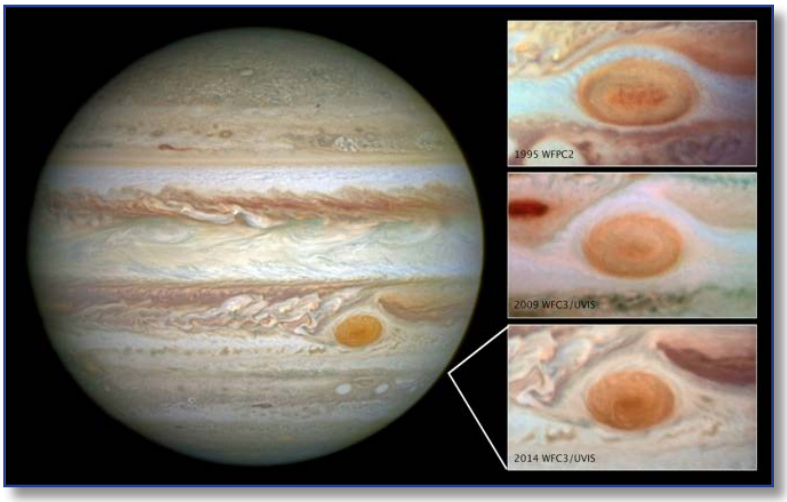
OSIRIS-REx is scheduled to launch in the fall of 2016, rendezvous with the asteroid Bennu in 2018, and return a sample of it to Earth in 2023. The spacecraft carries five instruments that will remotely evaluate the surface of Bennu. After more than a year of asteroid reconnaissance, the spacecraft will collect samples of at least 2 ounces (60 grams) and return them to Earth for scientists to study. "Successfully passing mission CDR is a major accomplishment, but the hard part is still in front of us — building, integrating, and testing the flight system in support of a tight planetary launch window," said Mike Donnelly, OSIRIS-REx project manager at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Key mission objectives focus on finding answers to basic questions about the composition of the very early solar system and the source of organic materials and water that made life possible on Earth. The mission will also aid NASA's asteroid initiative and support the agency's efforts to understand the population of potentially hazardous near-Earth objects and characterize those suitable for future asteroid exploration missions. The initiative brings together the best of NASA's science, technology, and human exploration efforts to achieve President Obama's goal of sending humans to an asteroid by 2025. "The OSIRIS-REx team has consistently demonstrated its ability to present a comprehensive mission design that meets all requirements within the resources provided by NASA," said Dante Lauretta, principal investigator from the University of Arizona, Tucson. "Mission CDR was no exception. This is a great team. I know we will build a flight and ground system that is up to the challenges of this ambitious mission."

In January, NASA invited people around the world to submit their names to be etched on a microchip onboard the spacecraft. After submitting their name, participants are able to download and print a certificate documenting their participation in the OSIRIS-REx mission. The campaign is open until September 30, 2014. For more information, visit *www.nasa.gov/osiris-rex*, *asteroidmission.org*, and *planetary.org/bennu*.

Hubble Shows Jupiter's Great Red Spot is Smaller than Ever Measured

Jupiter's trademark Great Red Spot — a swirling anti-cyclonic storm larger than Earth — has shrunk to its smallest size ever measured. According to Amy Simon of NASA's Goddard Space Flight Center in Greenbelt, Maryland, recent NASA Hubble Space Telescope observations confirm the Great Red Spot now is approximately 10,250 miles across. Astronomers have followed this downsizing since the 1930s.



Images of Jupiter's Great Red Spot, taken by the Hubble Space Telescope over a span of 20 years, shows how the planet's trademark spot has decreased in size over the years. Credit: NASA/ESA.

Historic observations as far back as the late 1800s gauged the storm to be as large as 25,500 miles on its long axis. NASA Voyager 1 and Voyager 2 flybys of Jupiter in 1979 measured it to be 14,500 miles across. In 1995, a Hubble photo showed the long axis of the spot at an estimated 13,020 miles across. And in a 2009 photo, it was measured at 11,130 miles across. Beginning in 2012, amateur observations revealed a noticeable increase in the rate at which the spot is shrinking — by 580 miles per year — changing its shape from an oval to a circle.

"In our new observations it is apparent very small eddies are feeding into the storm," said Simon. "We hypothesized these may be responsible for the accelerated change by altering the internal dynamics and

energy of the Great Red Spot." Simon's team plans to study the motions of the small eddies and the internal dynamics of the storm to determine whether these eddies can feed or sap momentum entering the upwelling vortex, resulting in this yet unexplained shrinkage. For more information, visit *www.nasa.gov/hubble* or *hubblesite.org*.

Largest Solar System Moon Detailed in Geologic Map

To present the best information in a single view of Jupiter's moon Ganymede, a global image mosaic was assembled, incorporating the best available imagery from NASA's Voyager 1 and 2 spacecraft and NASA's Galileo spacecraft. Credit: USGS Astrogeology Science Center/Wheaton/NASA/JPL-Caltech.

More than 400 years after its discovery by astronomer Galileo Galilei, the largest moon in the solar system — Jupiter's moon Ganymede — has finally been mapped in great detail. A group of scientists led by Geoffrey Collins of Wheaton College has produced the first global geologic map of Ganymede, Jupiter's seventh moon. The map combines the best images obtained during flybys conducted by NASA's Voyager 1 and 2 spacecraft (1979) and Galileo orbiter (1995 to 2003) and is now published by the U.S. Geological Survey as a global map. It technically illustrates the varied geologic character of Ganymede's surface and is the first global, geologic map of this icy, outer-planet moon. "This map illustrates the incredible variety of geological features on Ganymede and helps to make order from the apparent chaos of its complex surface," said Robert Pappalardo of NASA's Jet Propulsion Laboratory. "This map is helping planetary scientists to decipher the evolution of this icy world and will aid in upcoming spacecraft observations."

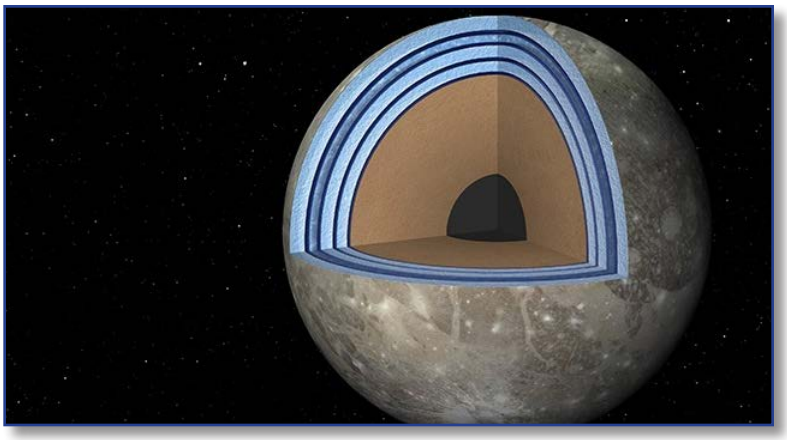
The European Space Agency's Jupiter Icy Moons Explorer mission is slated to be orbiting Ganymede around 2032. NASA is contributing a U.S.-led instrument and hardware for two European-led instruments for the mission. Since its discovery in January 1610, Ganymede has been the focus of repeated observation, first by Earth-based telescopes, and later by the flyby missions and spacecraft orbiting Jupiter. These studies depict a complex, icy world whose surface is characterized by the striking contrast between its two major terrain types: the dark, very old, highly cratered regions, and the lighter, somewhat younger (but still very old) regions marked with an extensive array of grooves and ridges.

To download the map, visit *www.jpl.nasa.gov/spaceimages/details.php?id=pia17902*.

Ganymede May Harbor "Club Sandwich" of Oceans and Ice

The largest moon in our solar system, a companion to Jupiter named Ganymede, might have ice and oceans stacked up in several layers like a club sandwich, according to new NASA-funded research that models the moon's makeup. Previously, the moon was thought to harbor a thick ocean sandwiched

between just two layers of ice, one on top and one on bottom. "Ganymede's ocean might be organized like a Dagwood sandwich," said Steve Vance of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, explaining the moon's resemblance to the "Blondie" cartoon character's multi-tiered sandwiches. The study, led by Vance, provides new theoretical evidence for the team's "club sandwich" model, first proposed last year. The research appears in the journal *Planetary and Space Science.*



This artist's concept of Jupiter's moon Ganymede, the largest moon in the solar system, illustrates the "club sandwich" model of its interior oceans. Credit: NASA/JPL-Caltech.

The results support the idea that primitive life might have possibly arisen on the icy moon. Scientists say that places where water and rock interact are important for the development of life; for example, it's possible life began on Earth in bubbling vents on our sea floor. Prior to the new study, Ganymede's rocky sea bottom was thought to be coated with ice, not liquid — a problem for the emergence of life. The "club sandwich" findings suggest otherwise: The first layer on top of the rocky core might be salty water.

NASA scientists first suspected an ocean in Ganymede in the 1970s, based on models of the large moon, which is bigger than Mercury. In the 1990s, NASA's Galileo mission flew by Ganymede, confirming the moon's ocean, and showing it extends to depths of hundreds of miles. The spacecraft also found evidence for salty seas, likely containing the salt magnesium sulfate. Previous models of Ganymede's oceans assumed that salt didn't change the properties of liquid very much with pressure. Vance and his team showed, through laboratory experiments, how much salt really increases the density of liquids under the extreme conditions inside Ganymede and similar moons. It may seem strange that salt can make the ocean denser, but you can see for yourself how this works by adding plain old table salt to a glass of water. Rather than increasing in volume, the liquid shrinks and becomes denser. This is because the salt ions attract water molecules. The models get more complicated when the different forms of ice are taken into account. The ice that floats in your drinks is called "Ice I." It's the least dense form of ice and lighter than water. But at high pressures, like those in crushingly deep oceans like Ganymede's, the ice crystal structures become more compact. "It's like finding a better arrangement of shoes in your luggage — the ice molecules become packed together more tightly," said Vance. The ice can become so dense that it is heavier than water and falls to the bottom of the sea. The densest and heaviest ice thought to persist in Ganymede is called "Ice VI."

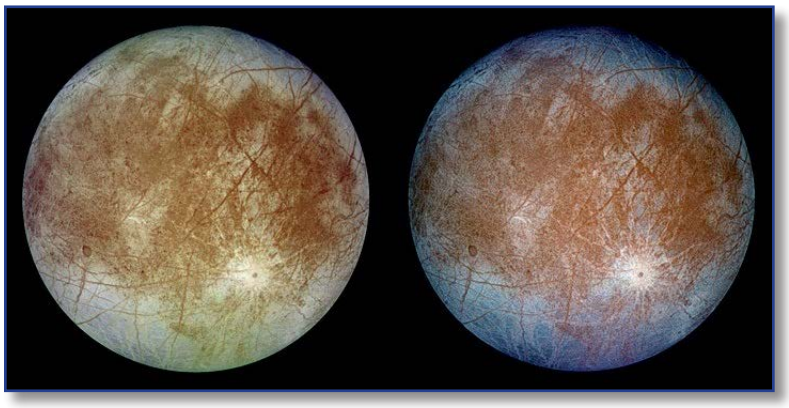
By modeling these processes using computers, the team came up with an ocean sandwiched between up to three ice layers, in addition to the rocky seafloor. The lightest ice is on top, and the saltiest liquid is heavy enough to sink to the bottom. What's more, the results demonstrate a possible bizarre phenomenon that causes the oceans to "snow upward." As the oceans churn and cold plumes snake around, ice in the uppermost ocean layer, called "Ice III," could form in the seawater. When ice forms, salts precipitate out. The heavier salts would thus fall downward, and the lighter ice, or "snow," would float upward. This

"snow" melts again before reaching the top of the ocean, possibly leaving slush in the middle of the moon sandwich. "We don't know how long the Dagwood-sandwich structure would exist," said Christophe Sotin of JPL. "This structure represents a stable state, but various factors could mean the moon doesn't reach this stable state."

The results can be applied to exoplanets too, planets that circle stars beyond our Sun. Some super-Earths, rocky planets more massive than Earth, have been proposed as "water worlds" covered in oceans. Could they have life? Vance and his team think laboratory experiments and more detailed modeling of exotic oceans might help find answers.

Ganymede is one of five moons in our solar system thought to support vast oceans beneath icy crusts. The other moons are Jupiter's Europa and Callisto and Saturn's Titan and Enceladus. The European Space Agency is developing a space mission, called JUpiter ICy moons Explorer (JUICE), to visit Europa, Callisto, and Ganymede in the 2030s. NASA and JPL are contributing to three instruments on the mission, which is scheduled to launch in 2022. For more information, visit *icyworlds.jpl.nasa.gov*.

NASA Seeks External Concepts for Mission to Oceanic Jovian Moon



This image shows two views of the trailing hemisphere of Jupiter's ice-covered satellite, Europa. The left image shows the approximate natural color appearance of Europa. The image on the right is a false-color composite version combining violet, green, and infrared images to enhance color differences in the predominantly water-ice crust of Europa. Credit: NASA.

NASA has issued a Request for Information (RFI) to science and engineering communities for ideas for a mission to Europa that could address fundamental questions of the enigmatic moon and the search for life beyond Earth. The RFI's focus is for concepts for a mission to Europa that costs less than $1 billion, excluding the launch vehicle that can meet as many of the science priorities as possible recommended by the National Research Council's 2011 Planetary Science Decadal Survey for the study of Europa. "This is an opportunity to hear from those creative teams that have ideas on how we can achieve the most science at minimum cost," said John Grunsfeld, associate administrator for the NASA Science Mission Directorate at the agency's headquarters in Washington. "Europa is one of the most interesting sites in our solar system in the search for life beyond Earth. The drive to explore Europa has stimulated not only scientific interest but also the ingenuity of engineers and scientists with innovative concepts."

NASA has studied a variety of mission designs and concepts in previous years and currently is funding the development of technologies that will be needed for the science instruments for a Europa mission. Congress appropriated $80 million for this work in Fiscal Year 2014, and the Fiscal Year 2015 budget proposal requests an additional $15 million.

Previous scientific findings point to the existence of a liquid water ocean located under the moon's icy crust. This ocean covers Europa entirely and contains more liquid water than all of Earth's oceans combined. The Decadal Survey deemed a mission to the Jupiter moon as among the highest priority scientific pursuits for NASA. It lists five key science objectives in priority order that are necessary to improve our understanding of this potentially habitable moon. The mission will need to characterize the extent of the ocean and its relation to the deeper interior; characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange; determine global surface, compositions, and chemistry, especially as related to habitability; understand the formation of surface features, including sites of recent or current activity, identify and characterize candidate sites for future detailed exploration; and understand Europa's space environment and interaction with the magnetosphere.

Early observations of Europa and Jupiter's other moons were limited to a single distant flyby of the satellites. NASA's Galileo spacecraft, launched in 1989 by the space shuttle, was the only mission to make repeated visits to Europa, passing close by the moon fewer than a dozen times. In December 2013, NASA's Hubble Space Telescope observed water vapor above the moon's frigid south polar region. This provided the first strong evidence of water plumes erupting off the moon's surface, although researchers are still working to verify the existence of these plumes.

Any mission to Europa must take into account the harsh radiation environment that would require unique protection of the spacecraft and instruments. In addition, spacecraft must meet planetary protection requirements intended to protect Europa's potentially habitable ocean. These requirements are very strict and involve ensuring that a viable Earth organism is not introduced into the Europa ocean. For more information, visit *solarsystem.nasa.gov/europa*.

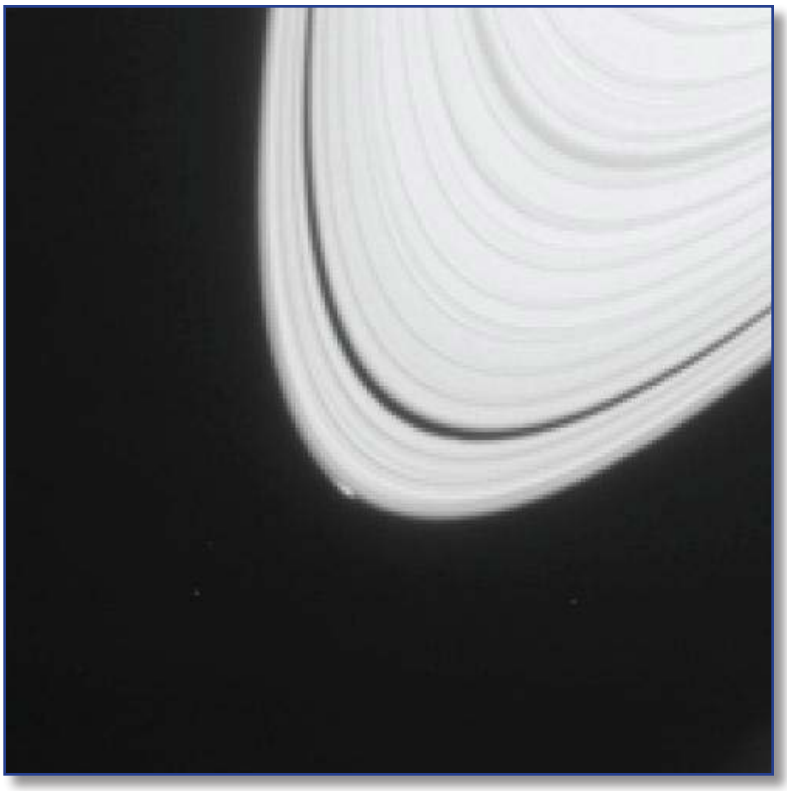
Cassini Images May Reveal Birth of a Saturn Moon

NASA's Cassini spacecraft has documented the formation of a small icy object within the rings of Saturn that may be a new moon, and may also provide clues to the formation of the planet's known moons. Images taken with Cassini's narrow angle camera on April 15, 2013, show disturbances at the very edge of Saturn's A ring — the outermost of the planet's large, bright rings. One of these disturbances is an arc about 20% brighter than its surroundings, 750 miles (1200 kilometers) long and 6 miles (10 kilometers) wide. Scientists also found unusual protuberances in the usually smooth profile at the ring's edge. Scientists believe the arc and protuberances are caused by the gravitational effects of a nearby object. Details of the observations were published online in the April 14 issue of the journal *Icarus*.

The object is not expected to grow any larger, and may even be falling apart. But the process of its formation and outward movement aids in our understanding of how Saturn's icy moons, including perhaps the cloud-wrapped Titan and ocean-holding Enceladus, may have formed in more massive rings long ago. It also provides insight into how Earth and other planets in our solar system may have formed and migrated away from our star, the Sun. "We have not seen anything like this before," said Carl Murray of Queen Mary University of London, the report's lead author. "We may be looking at the act of birth, where this object is just leaving the rings and heading off to be a moon in its own right."

The object, informally named Peggy, is too small to be seen in images so far. Scientists estimate it is probably no more than about a half mile (about a kilometer) in diameter. Saturn's icy moons range in size depending on their proximity to the planet — the farther from the planet, the larger. And many of Saturn's

moons are composed primarily of ice, as are the particles that form Saturn's rings. Based on these facts, and other indicators, researchers recently proposed that the icy moons formed from ring particles and then moved outward, away from the planet, merging with other moons on the way. "Witnessing the possible birth of a tiny moon is an exciting, unexpected event," said Cassini Project Scientist Linda Spilker, of NASA's Jet Propulsion Laboratory. Cassini's orbit will move closer to the outer edge of the A ring in late 2016 and provide an opportunity to study Peggy in more detail and perhaps even image it.



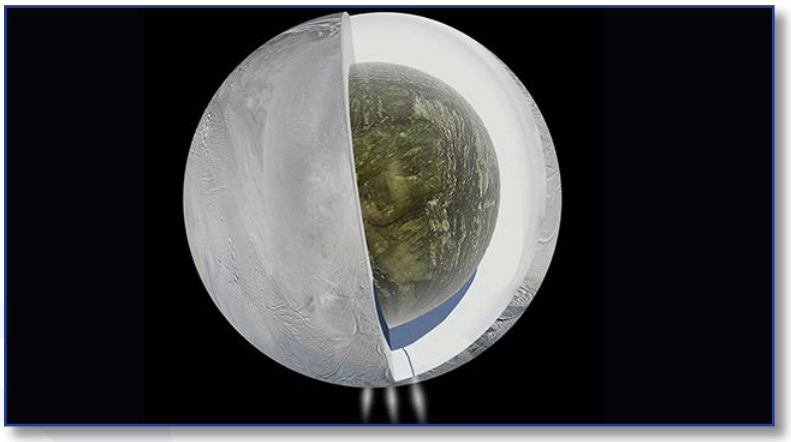
The disturbance visible at the outer edge of Saturn's A ring in this Cassini image could be caused by an object replaying the birth process of icy moons. Credit: NASA/JPL-Caltech/Space Science Institute.

It is possible the process of moon formation in Saturn's rings has ended with Peggy, as Saturn's rings now are, in all likelihood, too depleted to make more moons. Because they may not observe this process again, Murray and his colleagues are wringing from the observations all they can learn. "The theory holds that Saturn long ago had a much more massive ring system capable of giving birth to larger moons," Murray said. "As the moons formed near the edge, they depleted the rings and evolved, so the ones that formed earliest are the largest and the farthest out." For more information, visit *www.nasa.gov/cassini* or *saturn.jpl.nasa.gov*.

Cassini and Deep Space Network Detect Ocean Inside Saturn Moon

NASA's Cassini spacecraft and the Deep Space Network have uncovered evidence Saturn's moon Enceladus harbors a large underground ocean of liquid water, furthering scientific interest in the moon as a potential home to extraterrestrial microbes. Researchers theorized the presence of an interior reservoir of water in 2005 when Cassini discovered water vapor and ice spewing from vents near the moon's south pole. The new data provide the first geophysical measurements of the internal structure of Enceladus, consistent with the existence of a hidden ocean inside the moon. Findings from the gravity measurements are in an April edition of the journal *Science*.

"The way we deduce gravity variations is a concept in physics called the Doppler Effect, the same principle used with a speed-measuring radar gun," said Sami Asmar of NASA's Jet Propulsion Laboratory (JPL), a coauthor of the paper. "As the spacecraft flies by Enceladus, its velocity is perturbed by an amount that depends on variations in the gravity field that we're trying to measure. We see the change



Gravity measurements by NASA's Cassini spacecraft and Deep Space Network suggest that Saturn's moon Enceladus, which has jets of water vapor and ice gushing from its south pole, also harbors a large interior ocean beneath an ice shell, as this illustration depicts. Credit: NASA/JPL-Caltech.

in velocity as a change in radio frequency, received at our ground stations here all the way across the solar system." The gravity measurements suggest a large, possibly regional, ocean about 6 miles (10 kilometers) deep, beneath an ice shell about 19–25 miles (30–40 kilometers) thick. The subsurface ocean evidence supports the inclusion of Enceladus among the most likely places in our solar system to host microbial life. Before Cassini reached Saturn in July 2004, no version of that short list included this icy moon, barely 300 miles (500 kilometers) in diameter. "This then provides one possible story to explain why water is gushing out of these fractures we see at the south pole," said David Stevenson of the California Institute of Technology, one of the paper's co-authors.

Cassini has flown near Enceladus 19 times. Three flybys, from 2010 to 2012, yielded precise trajectory measurements. The gravitational tug of a planetary body, such as Enceladus, alters a spacecraft's flight path. Variations in the gravity field, such as those caused by mountains on the surface or differences in underground composition, can be detected as changes in the spacecraft's velocity, measured from Earth.

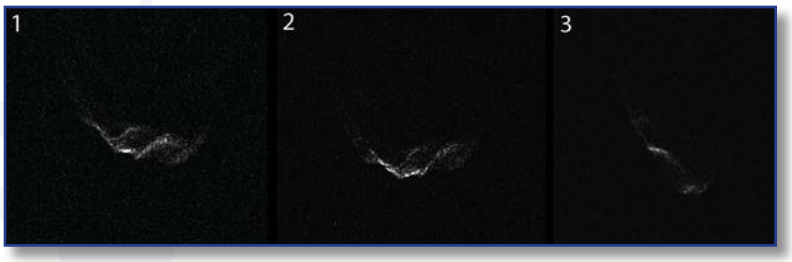
The technique of analyzing a radio signal between Cassini and the Deep Space Network can detect changes in velocity as small as less than 1 foot per hour (90 micrometers per second). With this precision, the flyby data yielded evidence of a zone inside the southern end of the moon with higher density than other portions of the interior. The south pole area has a surface depression that causes a dip in the local tug of gravity. However, the magnitude of the dip is less than expected given the size of the depression, leading researchers to conclude the depression's effect is partially offset by a high-density feature in the region, beneath the surface.

"The Cassini gravity measurements show a negative gravity anomaly at the south pole that however is not as large as expected from the deep depression detected by the onboard camera," said the paper's lead author, Luciano Iess of Sapienza University of Rome. "Hence the conclusion that there must be a denser material at depth that compensates the missing mass: very likely liquid water, which is 7% denser than ice. The magnitude of the anomaly gave us the size of the water reservoir."

There is no certainty the subsurface ocean supplies the water plume spraying out of surface fractures near the south pole of Enceladus; however, scientists consider it a real possibility. The fractures may lead down to a part of the moon that is tidally heated by the moon's repeated flexing, as it follows an eccentric orbit around Saturn. "Material from Enceladus' south polar jets contains salty water and organic molecules, the basic chemical ingredients for life," said Linda Spilker, Cassini's project scientist at JPL. "Their discovery expanded our view of the 'habitable zone' within our solar system and in planetary systems of other stars. This new validation that an ocean of water underlies the jets furthers understanding about this intriguing environment."

Arecibo Observatory Sees Comet 209P/LINEAR

The Arecibo Observatory planetary radar system observed periodic comet 209P/LINEAR from May 23 through May 27, 2014, finding it to be about 2.4 × 3 kilometers (1.5 × 1.8 miles) in size and elongated in shape. This is consistent with the size range suggested by optical observations, but is the first direct measurement of the nucleus dimensions. Discovered by the Lincoln Near-Earth Asteroid Research project in 2004, 209P/LINEAR was responsible for the recent Camelopardalids meteor shower of May 2014.



Several features are visible on the comet, perhaps ridges or cliffs. This is only the fifth comet nucleus imaged by Arecibo in the last 16 years, and the most detailed. Resolution in the vertical direction is 7.5 meters (25 feet) per pixel. Radar imaging produces a projection of the object that will be analyzed in the weeks ahead to determine the true appearance of the comet nucleus. Earth is at the bottom of these images. Credit: Arecibo Observatory/NASA/Ellen Howell, Patrick Taylor.

Comets rarely come this close to Earth, making it an extraordinary opportunity to get images of the surface. Observations were led by the Universities Space Research Association's (USRA) astronomer Dr. Ellen Howell, who specializes in studying comets and asteroids using radar, as well as passive radio and infrared spectroscopy techniques to determine the surface and coma properties of small solar system bodies. The planetary radar group at Arecibo Observatory is led by deputy director Dr. Michael Nolan, also of USRA.

With a rotation period of approximately 11 hours, as determined by Carl Hergenrother at the University of Arizona using the 1.8-meter VATT telescope, this comet is one of the many Jupiter-family comets, which orbit the Sun twice for every time Jupiter orbits once. Comet 209P's orbit brings it by Earth once every five years. However, this comet will be out of reach for radar imaging again for at least 50 years — close approaches of comets are extremely rare events. In fact, this is the closest known comet to pass by Earth since 1983 (Comet IRAS-Araki-Alcock), and although Comet 209P/LINEAR is periodic, and orbits the Sun every 5 years or so, there will not be another radar observing opportunity for the foreseeable future.

Comets have a central nucleus made of ice, dust, and rocks, and a coma of dust and gas. Two tails, one made of ions and one of dust, form in the direction away from the Sun. Six comet nuclei have been imaged by spacecraft, which reveals a wide variety of surface features and structures on these icy objects.

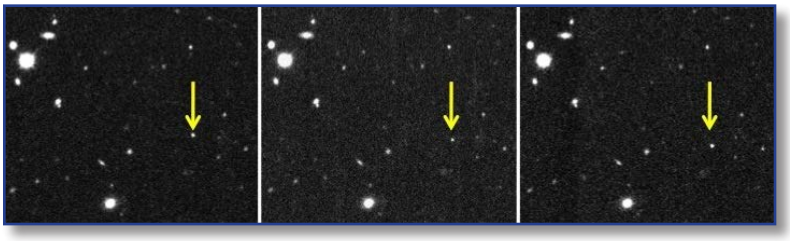
Howell led a team which included USRA researchers Dr. Patrick Taylor, Alessondra Springmann, Linda Rodriguez Ford, and Luisa Zambrano Marin. "Comet 209P/LINEAR has no chance of hitting Earth," said data analyst Alessondra Springmann. "It comes no closer than 8.3 million kilometers (5.2 million miles) to Earth, safely passing our planet."

Arecibo Observatory and the complementary Goldstone Solar System Radar in California run by NASA's Jet Propulsion Laboratory both observed Comet 209P/LINEAR during its pass by Earth in May. These radar facilities are unique among telescopes on Earth for their ability to resolve features on comets and asteroids, while most optical telescopes on the ground would see these cosmic neighbors simply as unresolved points of light. Arecibo radar has observed other comets, including 103P/Hartley 2 in

2010, 8P/Tuttle in 2007 and 2008, and 73P/Schwassmann-Wachmann 3 in 2006. These images of 209P/LINEAR are the highest-resolution comet radar images obtained to date.

Located in Puerto Rico, the Arecibo Observatory is home to the world's largest and most sensitive single-dish radio telescope, at 305 meters (1000 feet) across. This facility dedicates hundreds of hours a year of its telescope time to improving our knowledge of near-Earth asteroids and comets. For more information, visit *www.naic.edu*.

NASA-Supported Research Helps Redefine Solar System's Edge



These images show the discovery of 2012 VP113 taken about 2 hours apart on November 5, 2012. The motion of 2012 VP113 stands out compared to the steady-state background of stars and galaxies. Credit: Scott Sheppard/Carnegie Institution for Science.

The solar system has a new most-distant family member. Scientists using groundbased observatories have discovered an object that is believed to have the most distant orbit found beyond the known edge of our solar system. Named 2012 VP113, the observations of the object — possibly a dwarf planet — were obtained and analyzed with a grant from NASA. A dwarf planet is an object in orbit around the Sun that is large enough to have its own gravity pull itself into a spherical, or nearly round, shape. The detailed findings were published in the March 27 edition of *Nature*.

"This discovery adds the most distant address thus far to our solar system's dynamic neighborhood map," said Kelly Fast, discipline scientist for NASA's Planetary Astronomy Program, Science Mission Directorate (SMD) at NASA Headquarters, Washington. "While the very existence of the inner Oort cloud is only a working hypothesis, this finding could help answer how it may have formed."

The observations and analysis were led and coordinated by Chadwick Trujillo of the Gemini Observatory in Hawaii and Scott Sheppard of the Carnegie Institution in Washington. They used the National Optical Astronomy Observatory's 13-foot (4-meter) telescope in Chile to discover 2012 VP113. The Magellan 21-foot (6.5-meter) telescope at Carnegie's Las Campanas Observatory in Chile was used to determine the orbit of 2012 VP113 and obtain detailed information about its surface properties.

"The discovery of 2012 VP113 shows us that the outer reaches of our solar system are not an empty wasteland as once was thought," said Trujillo, lead author and astronomer. "Instead, this is just the tip of the iceberg telling us that there are many inner Oort cloud bodies awaiting discovery. It also illustrates how little we know about the most distant parts of our solar system and how much there is left to explore."

Sedna was discovered beyond the Kuiper belt edge in 2003, and it was not known if Sedna was unique, as Pluto once was thought to be before the Kuiper belt was discovered in 1992. With the discovery of 2012 VP113, Sedna is not unique, and 2012 VP113 is likely the second known member of the hypothesized inner Oort cloud. The outer Oort cloud is the likely origin of some comets. "Some of these inner Oort cloud objects could rival the size of Mars or even Earth," said Sheppard. This is because many

of the inner Oort cloud objects are so distant that even very large ones would be too faint to detect with current technology."

2012 VP113's closest orbit point to the Sun brings it to about 80 times the distance of Earth from the Sun, a measurement referred to as an astronomical unit (AU). The rocky planets and asteroids exist at distances ranging between 0.39 and 4.2 AU. Gas giants are found between 5 and 30 AU, and the Kuiper belt (composed of hundreds of thousands of icy objects, including Pluto) ranges from 30 to 50 AU. In our solar system there is a distinct edge at 50 AU. Until 2012 VP113 was discovered, only Sedna, with a closest approach to the Sun of 76 AU, was known to stay significantly beyond this outer boundary for its entire orbit.

Both Sedna and 2012 VP113 were found near their closest approach to the Sun, but they both have orbits that go out to hundreds of astronomical units, at which point they would be too faint to discover. The similarity in the orbits found for Sedna, 2012 VP113, and a few other objects near the edge of the Kuiper belt suggests the new object's orbit might be influenced by the potential presence of a yet unseen planet perhaps up to 10 times the size of Earth. Further studies of this deep space arena will continue. For more details on 2012 VP113, visit *home.dtm.ciw.edu/users/sheppard/inner_oort_cloud*.

45th Lunar and Planetary Science Conference

March 17–21, 2014,
The Woodlands, Texas

The 45th Lunar and Planetary Science Conference (LPSC), held in March at The Woodlands Waterway Marriott Hotel and Convention Center in The Woodlands, Texas, was a huge success. While the participation numbers (1934 abstracts submitted; 1709 attendees) were down slightly from the previous two years, they reflected a return to the traditional growth pattern experienced for this conference, rather than the anomalous spike in participation experienced in 2012 and 2013. Once again student attendance made up more than 31% of the overall number of participants, again reflecting that LPSC is a meeting that is both accessible and important to young scientists.

Participants enjoy greeting old friends and colleagues during the Sunday night welcome event.

Participants circulate among hundreds of posters during the poster session and exhibitor showcase.

LPSC, co-chaired by Stephen Mackwell of the Lunar and Planetary Institute and Eileen Stansberry of the NASA Johnson Space Center, began with the usual Sunday evening registration and welcome event. The welcome event was held in the Waterway Ballrooms, giving participants an opportunity to meet and greet more of their friends and colleagues. Many participants have said that one of the appealing qualities of the meeting is that it feels as much like a homecoming or reunion event as a scientific conference, and this was in evidence on Sunday night from the smiles, hugs, and earnest conversations held among attendees.

On Monday morning, the oral sessions began. The conference featured five full (very full!) days of sessions, featuring such topics as impacts, planetary dynamics, planetary aeolian processes, planetary volcanism and igneous processes, exobiology, cosmochemical origins, early solar system chronology, small bodies,

During the Masursky Lecture, Dave Scott discussed Harold ("Hal") Masursky's contributions to Apollo 15, and the manner in which human exploration capabilities of today can be applied to four other specific lunar sites identified by Masursky and observed during Apollo 15.

Winners of the 2014 LPI Career Development Award, which is given to graduate students who are the first author of an abstract submitted to LPSC and selected for presentation.

outer planets, meteorites, martian geochemistry, lunar studies, mission concepts, and much, much more. Special sessions included Lunar Dust and Exosphere Featuring the First Results from LADEE, Structure and Evolution of Planetary Bodies: A Geophysical Perspective, New Perspectives of the Moon: Enabling Future Lunar Missions, and Fluids on Differentiated Bodies. The complete program and abstracts are available at *www.hou.usra.edu/meetings/lpsc2014*.

The plenary session on Monday afternoon featured the Masursky Lecture by Apollo 15 Mission Commander Col. David R. Scott, USAF (Retired), entitled "Masursky's Moon and the Science of Apollo 15." The session also recognized the winners of the 2013 Dwornik Awards, the 2014 LPI Career Development Awards, and the McGetchin Memorial Scholarship.

During the lunch hour on Monday, a number of peripheral activities took place, including a featured talk by Harrison ("Jack") Schmitt entitled "Apollo 17: New Insights from Field Notes, Photodocumentation, and Analytical Data." Schmitt, who was Apollo 17's Lunar Module Pilot, became the 12th and final man — and only trained geologist — to set foot on the Moon. Monday evening activities included the NASA Headquarters Briefing, featuring Jim Green and Jonathan Rall of NASA's Science Mission Directorate, as well as the opening of the Exhibitor Showcase and a Student/Scientist Networking Event.

Tuesday through Friday continued with two poster sessions and many more oral sessions. Other topics covered during the week included presolar grains, interplanetary dust particles, Venus, Mercury, material and environmental analogs, and education and public outreach. The conference concluded on Friday afternoon.

The NASA booth at the LPSC Exhibitor Showcase featured a model of the Curiosity rover.

For the second year in a row, the conference utilized LPSC Microbloggers to use social media to provide real-time coverage of the science presented during the sessions. Combined with a Twitter feed on the meeting website, this coverage not only allowed participants to know what was going on in the sessions they were unable to attend, but also provided information for those in other parts of the world who were not able to make it to the meeting. This was also the second year that the conference utilized e-posters, which not only gave more visibility to the posters of the presenters who chose to upload their posters, but also provided yet another way for non-attendees to have more access to the science presented at the meeting.

Plans are already underway for the 46th LPSC, which is scheduled for March 16–20, 2015. Mark your calendars! Meeting announcements and other details will be available soon.

Workshop on Venus Exploration Targets

May 19–21, 2014, Houston, Texas

Venus and Earth are intriguingly similar in terms of their size, density, and bulk composition, but that's where the resemblance ends. Earth's next-door neighbor is hellishly hot, devoid of oceans, lacking plate tectonics, and bathed in a thick, reactive atmosphere. How, why, and when did Earth's and Venus' evolutionary paths diverge? These fundamental and unresolved questions drive the need for vigorous new exploration of Venus. The answers are central to understanding Venus in the context of terrestrial planets and their evolutionary processes. More importantly, Venus can provide important clues to understanding our own planet — how it has maintained a habitable environment for so long and how long it can continue to do so. Yet Venus remains the least understood of all planetary bodies in the inner solar system.

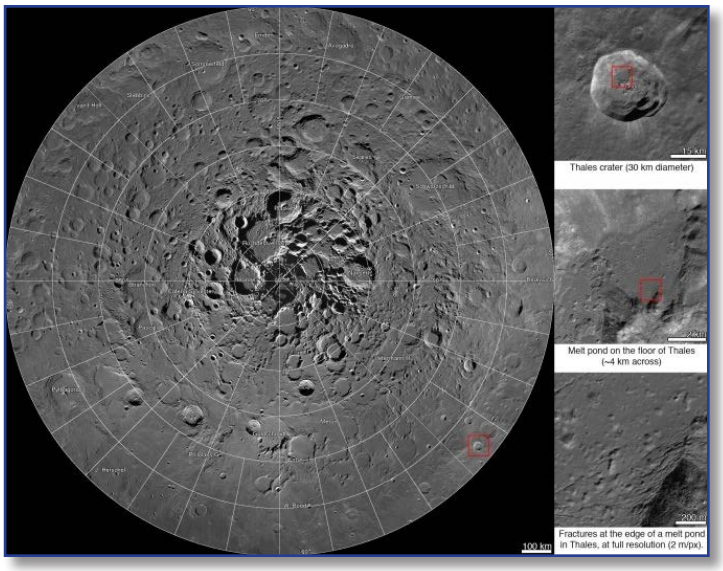
To spur new exploration activities at Venus, the Venus Exploration Analysis Group (VEXAG) recently led development of three community-endorsed documents: the *Goals, Objectives, and Investigations Report*; the *Roadmap for Venus Exploration*; and the *Venus Technology Plan*. These documents are available on the VEXAG website at *www.lpi.usra.edu/vexag/*.

In May, 54 scientists from around the globe converged at the Lunar and Planetary Institute (LPI) in Houston at a workshop organized by LPI staff scientist Dr. Virgil L. (Buck) Sharpton to identify key targets for future exploration of Venus and to evaluate their potential for answering the fundamental questions posed in the VEXAG reports. A set of oral and poster presentations on the first day set the

stage for topical breakout sessions held throughout the remainder of the workshop. Breakout groups were organized around where the science payload would be located: on the surface, within the atmosphere, or from orbit. Each group was tasked not only with providing specific science justification for each target, but also providing guidance on instrument and mission constraints needed to meet the science objectives. Following each half-day breakout session, group chairs summarized their progress for plenary discussion. The complete workshop program and abstracts are available at *www.hou.usra.edu/meetings/venus2014*.

The surface group was chaired by Larry Esposito (University of Colorado); Kevin McGouldrick (Southwest Research Institute) led the group focused on atmospheric probes, balloons, etc.; and the orbital science group was headed by Lori Glaze (NASA Goddard Spaceflight Center). Detailed workshop results are being compiled, and the document will be made available on the VEXAG website.

NASA Releases First Interactive Mosaic of Lunar North Pole



A new interactive mosaic from NASA's Lunar Reconnaissance Orbiter covers the north pole of the Moon from 60° to 90°N latitude at a resolution of 6.5 feet (2 meters) per pixel. Close-ups of Thales crater (right side) zoom in to reveal increasing levels of detail. Credit: NASA/GSFC/Arizona State University.

Scientists using cameras onboard NASA's Lunar Reconnaissance Orbiter (LRO) have created the largest high-resolution mosaic of our Moon's north polar region. The 6.5-feet (2-meters)-per-pixel images cover an area equal to more than one-quarter of the United States. Web viewers can zoom in and out and pan around an area. Constructed from 10,581 pictures, the mosaic provides enough detail to see textures and subtle shading of the lunar terrain. Consistent lighting throughout the images makes it easy to compare different regions. "This unique image is a tremendous resource for scientists and the public alike," said John Keller, LRO project scientist at NASA's Goddard Space Flight Center. "It's the latest example of the exciting insights and data products LRO has been providing for nearly five years."

The images making up the mosaic were taken by the two LRO Narrow Angle Cameras, which are part of the instrument suite known as the Lunar Reconnaissance Orbiter Camera (LROC). The cameras can record a tremendous dynamic range of lit and shadowed areas. "Creation of this giant mosaic took four years and a huge team effort across the LRO project," said Mark Robinson, principal investigator for the LROC at Arizona State University in Tempe. "We now have a nearly uniform map to unravel key science questions and find the best landing spots for future exploration."

The entire image measures 931,070 pixels square — nearly 867 billion pixels total. A complete printout at 300 dots per inch — considered crisp resolution for printed publications — would require a square sheet of paper wider than a professional U.S. football field and almost as long. If the complete mosaic were processed as a single file, it would require approximately 3.3 terabytes of storage space. Instead, the processed mosaic was divided into millions of small, compressed files, making it manageable for users to view and navigate around the image using a web browser. To view the image with zoom and pan capability, visit *lroc.sese.asu.edu/images/gigapan*.

LRO entered lunar orbit in June 2009 equipped with seven instrument suites to map the surface, probe the radiation environment, investigate water and key mineral resources, and gather geological clues about the Moon's evolution. Researchers used additional information about the Moon's topography from LRO's Lunar Orbiter Laser Altimeter, as well as gravity information from NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission, to assemble the mosaic. Launched in September 2011, the GRAIL mission, employing twin spacecraft named Ebb and Flow, generated a gravity field map of the Moon — the highest-resolution gravity field map of any celestial body. For more information, visit *lro.gsfc.nasa.gov* or *lroc.sese.asu.edu*.

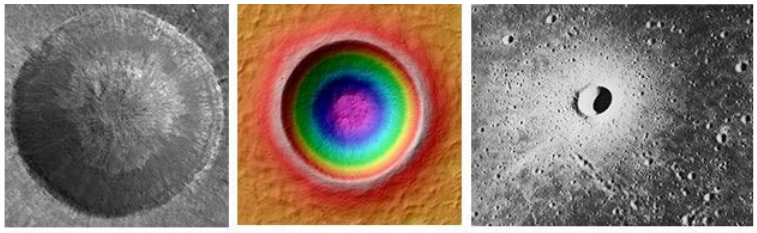
SPICE Domestic Training Class Offered

SPICE is an ancillary information system providing scientists and engineers access to spacecraft orbit, attitude, and similar information needed to determine observation geometry used in planning and analyzing space science observations. SPICE is frequently used for mission engineering functions as well. The SPICE system was conceived for and remains primarily focused on solar system exploration (planetary) missions, but has also proven useful for a variety of other purposes.

NASA's Navigation and Ancillary Information Facility (NAIF) at the Jet Propulsion Laboratory (JPL) is offering a SPICE training class in Columbia, Maryland, on October 21–23, 2014. This class will be very similar to previous SPICE classes, and should not be considered as a beginner's class. The class is intended for those who will write software that will make use of SPICE data, and is not well suited for those whose principal job is producing SPICE kernels unless the student is rather new to SPICE — the focus is mostly on using (consuming) kernels.

For more information about SPICE, visit *naif.jpl.nasa.gov*. Details about the training class are available at *naif.jpl.nasa.gov/naif/WS2014_announcement.html*.

New Impact Cratering Resource Site



The LPI-JSC Center for Lunar Science and Exploration (CLSE) has prepared a new set of products to help faculty teach the subject of impact cratering. In the spirit of LPI's traditional slide sets and image gallery (*www.lpi.usra.edu/publications/slidesets/*) that are used at universities across the country, a new series of video simulations of impact cratering processes has been developed for similar classroom use.

"Video Simulations of Impact Cratering Processes" can be found at *www.lpi.usra.edu/exploration/training/resources/impact_cratering*. The videos explore how impactor size and velocity, as well as target gravity and temperature, affect the sizes and morphologies of impact craters. The videos can be run in real time from the website or, if users prefer, downloaded to their own computers.

Comparisons between the craters produced in the simulations and actual craters on the Moon (e.g., Linné, Armstrong, St. George, Schwarzschild, Schrödinger, Orientale, South Pole-Aitken basin) and Earth (e.g., Chicxulub, Flynn Creek, Steinheim) are provided, with links to additional data associated with those structures.

For more information about other higher education resources available from CLSE, visit *www.lpi.usra.edu/exploration/training/resources*.

"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.

Upcoming Public Event Opportunities

Planetary scientists and educators may want to prepare for upcoming opportunities to engage the public in events around planetary mission arrivals. In a few months, MAVEN arrives at Mars; in 2015, Dawn will go into orbit around the dwarf planet Ceres; and just a few months later, New Horizons will fly past the dwarf planet Pluto. Host your own events this year! These planetary opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration, solar system formation and evolution, Mars exploration, planetary geology, and habitability!

International Observe the Moon Night —

Celebrate the Moon! September 6, 2014, will mark the fifth International Observe the Moon Night! There are opportunities to host and advertise your own event as well as to connect with events within your community. Activities, information about the Moon, suggestions on hosting an event, and details about events at international partnering institutes are all available online at *observethemoonnight.org*.

MAVEN at Mars —

This past November, NASA launched the Mars Atmosphere and Volatile Evolution (MAVEN) mission in the hope of understanding how and why the planet has been losing its atmosphere over billions of years. MAVEN is on track to arrive at Mars on September 21, 2014. MAVEN Education resources are available online at *lasp.colorado.edu/home/maven/education-outreach*.

Dawn Arrives at Ceres —

The Dawn mission left the asteroid Vesta in 2012 and is on its way to dwarf planet Ceres, the largest asteroid. It is expected to arrive in spring 2015. A variety of educational materials are available at *dawn.jpl.nasa.gov/education*.

New Horizons Reaches Pluto —

The New Horizons mission launched back in 2006 for distant Pluto, and will fly past this mysterious icy dwarf planet in July 2015. Information and resources for your Pluto celebrations are available at *pluto.jhuapl.edu/education/index.php*.

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

The Astronomical Society of the Pacific's 2014 Annual Meeting will be held August 4–6, 2014, at the Hyatt Regency in Burlingame, California, just south of San Francisco. Join the ASP and your Education and Public Outreach (E/PO) colleagues and professional peers to explore the latest in formal and informal education best practices. Engage and network over three days of presentations, panels, and workshops — and learn from some of the leading experts in our field!

Scheduled plenaries, panels, and workshops include a discussion with high-level STEM agency administrative officials (tackling Co-STEM and the future of federal funding and programs in STEM education/outreach); an interactive plenary discussion with panelists sharing their perspectives from working with diverse audiences; a "Working with Scientists Who Interact with Public Audiences" plenary, about enhancing the science communication skills of research scientists; a "Next Generation Science Standards (NGSS)" plenary to address implications for schools, school districts, and teacher professional development providers; a panel on "Weighing the Balance of Science Literacy in Education and Public Policy"; a presentation on connections across formal and informal STEM learning; and sessions on NASA EPO impacts and metrics, public science literacy, "big science," and amateur astronomers' impact on research and outreach.

More information is available at *www.astrosociety.org/education/asp-annual-meeting*.

Cross-Forum Education and Public Outreach Retreat

The 2014 NASA Science Mission Directorate Cross-Forum Education and Public Outreach (E/PO) retreat will be co-located with the ASP annual meeting, and will begin Sunday, August 3, in Burlingame, California. Highlighted sessions will include networking, Co-STEM, and the future of E/PO, which were the most-requested topics on the pre-retreat survey. Virtual participation will be available for select portions of the retreat. There will also be professional development opportunities on Monday as part of the ASP meeting. For more information, contact *planetaryforum@lpi.usra.edu*.

Eugene Shoemaker Impact Cratering Award

The Eugene M. Shoemaker Impact Cratering Award is for undergraduate or graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. The award, which will include $2500.00, is to be applied toward the study of impact craters, either on Earth or on the other solid bodies in the solar system; areas of study may include but are not necessarily limited to impact cratering processes, the bodies that make the impacts, or the geological, chemical, or biological results of impact cratering. The application deadline is August 29, 2014. For more information, visit *www.lpi.usra.edu/science/kring/Awards/Shoemaker_Award*.

Field Training and Research Program at Meteor Crater

The LPI-JSC Center for Lunar Science and Exploration announces a student field camp opportunity coming this fall. The Field Training and Research Program at Meteor Crater, organized under the auspices of the NASA Solar System Exploration Research Virtual Institute (SSERVI), is a week-long geology field class and research project based at Barringer Meteorite Crater, Arizona. The goal will be to introduce students to impact cratering processes and provide an opportunity to assist with a research project at the crater. Skills developed during the field camp should better prepare the students for their own thesis studies in impact-cratered terrains, whether they be on Earth, the Moon, asteroids, Mars, or some other solar system planetary surface.

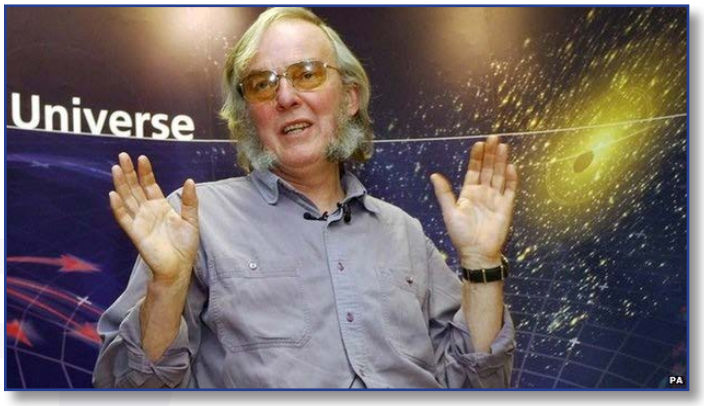
The field camp is designed for graduate college students in geology and planetary science programs, although advanced undergraduate students will be considered if they have successfully completed a summer field geology program and have a demonstrated interest in impact cratering processes. U.S. and international students are eligible to apply. The field camp is offered October 4–12, 2014, and is limited to 16 participants. Interested candidates should apply by July 11, 2014, to be considered. For more information, visit *www.lpi.usra.edu/exploration/mcFieldCamp*.

"Unheard Voices" Resource Guides

"Unheard Voices," a set of resource guides about the astronomy of many cultures and about the contributions of women to astronomy, is now available on the Multiverse website at *multiverse.ssl.berkeley.edu/Learning-Resources/Educator-Resource-Guides*.

The two resource guides are sponsored by the Heliophysics Forum of the Space Missions Directorate at NASA, and include a variety of materials, many of which can be used directly in the classroom, for student papers, or personal enrichment. "Unheard Voices 1: The Astronomy of Many Cultures" features the contributions to astronomy of African, Asian, Hispanic, South Pacific, Islamic, and Native American cultures, together with a section on reports and articles for achieving greater diversity in science. "Unheard Voices 2: Women in Astronomy" features sections on the history of women in astronomy in general, materials on selected women astronomers of the past, issues facing women in astronomy today, and materials on selected contemporary women astronomers.

Colin Pillinger, 1943–2014



British planetary scientist Colin Pillinger, best known for his 2003 attempt to land a spacecraft on Mars, has died at the age of 70. Pillinger was at his home in Cambridge when he suffered a brain hemorrhage and fell into a deep coma. He died later at Addenbrooke's Hospital without regaining consciousness.

Pillinger established himself early in his career as an expert in the chemical properties of extraterrestrial objects, working for NASA studying samples from the Apollo mission to the Moon and from meteorites. He was the driving force behind Beagle-2, which was built to search for life on Mars. He brought plenty of British eccentricity to the mission, his face framed by robust sideburns that raced to his chin, his eyes dancing behind thick, tinted glasses. But Pillinger, who taught planetary and space science at the Open University in Milton Keynes, England, for 35 years, also brought charm, enthusiasm, and scientific credibility, and he convinced the British government and private donors in Europe that the countries that had led exploration across much of the world should extend their ambitions. Cobbling together $120 million — $40 million of it from the government — he helped design a Mars lander named Beagle-2, in honor of the H.M.S. Beagle, the ship on which Charles Darwin sailed while doing the research that led to his theories of evolution.

The craft was carried piggyback to the Red Planet on a European satellite, but unfortunately vanished without trace after being dropped off to make its landing. But Pillinger continued to push space agencies to complete what he called "unfinished business on Mars," and was often critical of the delays that have seen Europe's follow-up rover mission, ExoMars, slip back to 2018.

At the age of 62, Pillinger was diagnosed with multiple sclerosis, which made it difficult for him to walk. But he refused to let the illness diminish his research, and his motorized buggy was often seen racing around scientific conferences. With colleagues at the Open University, where he headed the Department of Physical Sciences until 2005, he was keenly looking forward to this year's Rosetta mission. When the European spacecraft Rosetta ends its 10-year journey by meeting the Comet 67P Churyumov/Gerasimenko, it will deploy a small gas chromotograph mass spectrometer experiment to investigate the object's chemistry. The lead investigator for the experiment is named as Colin Pillinger.

Dr. David Parker, the chief executive of the UK Space Agency, said that Pillinger had played a critical role in raising the profile of the British space program and had inspired "young people to dream big dreams." Added Parker, "It's important to note that Colin's contribution to planetary science goes back to working on Moon samples from Apollo, as well as his work on meteorites. While we still don't know for certain what happened to Beagle-2, I'd say that the project was a turning point in bringing together the space science and industrial communities in the UK — which didn't used to speak with one voice. Beagle-2 wasn't built in Colin's backyard: It was the product of UK brains and hard-work in many companies and universities."

For the British media, Pillinger was often the go-to man for a comment when a new piece of space science was published. The press appreciated his straight-talking, and the whiskers and the Bristolian

accent just added to his appeal. He had an especially sharp eye for a good headline, once demonstrating the relatively small scale of Beagle-2 by loading a replica into a supermarket trolley and wheeling it through the car park of the Open University. The footage was picked up by the satirical programme "Have I Got News for You?," ensuring that news of the mission reached a far wider audience.

— Portions of text excerpted from the BBC and The New York Times

Gordon Swann, 1931–2014

Geologist Gordon A. Swann left for another world on May 22, 2014. Swann was born in Palisade, Colorado, on September 21, 1931, and remained in Colorado to graduate from high school in in 1949. After serving in the U.S. Navy from 1952 to 1956, he returned to the University of Colorado to attain a Ph.D. in 1962, one of the pioneers in a study of the Precambrian geology of the Front Range of Colorado. His career in the U.S. Geological Survey (USGS) began in Denver in 1963 and moved to Flagstaff in 1964. He trained astronauts to perform lunar geologic investigations, educated NASA bureaucrats, and planned missions throughout the Apollo program of manned planetary studies. He was responsible for designing the goals and procedures that the Apollo astronauts would use to explore, photograph, and sample the Moon. One of his special accomplishments was personally demonstrating to doubting NASA astronauts that real geological science could be carried out by while constrained inside the confining space suit used on the missions. Following the lunar studies, Swann served as Deputy Assistant Regional Geologist for the Center of Astrogeology and adjunct professor at Northern Arizona University, teaching and serving as a thesis advisor. Adding to the admiration of his colleagues, Swann also received professional awards, including the NASA Medal for Scientific Achievement and the American Institute of Professional Geologists Excellence Award. In recognition of the respect accorded him, the asteroid "Swann" was named for him.

As a young scientist with the USGS, Swann endured hours inside a simulated space pressure suit, sweating on hot Arizona plateaus, trying to understand what tasks spacesuit-wearing astronauts could and could not do on the lunar surface. Swann also mapped potential exploration sites from Lunar Orbiter images, certifying that the smooth areas in the nearside maria were safe for human landings. He was part of the scientific team for each lunar landing and was the Principal Investigator of the Field Geology experiment on the Apollo 13, 14, and 15 missions. He will be remembered and celebrated as a key player in the surface exploration portion of the Apollo program.

Besides his professional excellence, Swann served as Master of Flagstaff Masonic Lodge No. 7 in 1986. He was also honored by being awarded the Thirty-Third Degree of the Ancient and Accepted Scottish Rite Masons and received two Albert Pike awards for his work in the Scottish Rite degrees in the Tucson Consistory.

— Portions of text excerpted from the Arizona Daily Sun

Frederick A. (Fred) Tarantino, 1955–2014

Dr. Frederick A. (Fred) Tarantino, former President and Chief Executive Officer of the Universities Space Research Association (USRA), passed away on June 9. USRA is a national, nonprofit consortium of universities that was chartered in 1969 by the National Academy of Sciences at the request of NASA, and is now a scientific research and advanced technology company operating programs and institutes, including the Lunar and Planetary Institute in Houston, Texas, that are focused on research and education in most of the disciplines engaged in space-related science and engineering. Tarantino left a lasting imprint during his tenure at USRA, guiding it to the best year in its history in 2013.

Tarantino obtained a B.S. degree in Physics from Rensselaer Polytechnic Institute, an M.S. in Nuclear Science from the Air Force Institute of Technology, and a Ph.D. in Nuclear Reactor Physics from MIT. He was also a graduate of the Wharton Business School's Advanced Management Program. During a 19-year career with the U.S. Army, Tarantino served as U.S. chair of the joint U.S.-U.K. working group on space power, and led a mission to Russia to procure over 100 tons of advanced Soviet space hardware; he then designed, built, and operated a special test facility for it. Tarantino later was Defense Liaison in the White House Office of Science and Technology Policy, serving as Executive Assistant to the National Security Council Senior Director for Science and Technology. After this, he was appointed Chief of the Air and Missile Defense Branch in the Office of the Secretary of the Army.

Following his military career, Tarantino joined the Bechtel Corporation, where he rose to become President and General Manager of Bechtel Nevada Corporation, responsible for management and operations of the Nevada Test Site and eight associated operating locations. After eight years with Bechtel, Tarantino was appointed Principal Associate Director, Nuclear Weapons Program, at the Los Alamos National Laboratory, where he directed all aspects of a $1.4 billion per year science-based weapons stewardship program.

Lucas Kamp, 1946–2014

Lucas Kamp died of cancer on March 30, 2014. He had been ill for approximately one year, but continued his work planning for the Microwave Instrument for the Rosetta Orbiter (MIRO) cometary observations and analyzing Galileo Near-Infrared Mapping Spectrometer (NIMS) data right up until his death. Kamp was born on March 15, 1946, in Kingston-on-Thames, England, U.K. He was raised in the Netherlands, and spoke four languages: English, Dutch, German, and French. Kamp received an A.B. in Astrophysical Sciences from Princeton University in 1968. Following that degree he received a Masters' degree in 1970 and a Ph.D.in 1972 from the University of Chicago, both in Astronomy and Astrophysics.

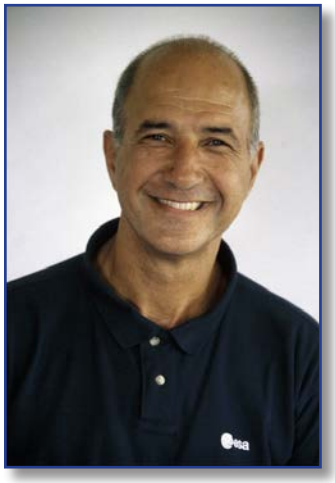
From 1972 to 1974, Kamp was an NRC Research Affiliate at the NASA Goddard Space Flight Center in Greenbelt, Maryland. His work consisted of research in model stellar atmospheres, spectroscopy, and

radiative transfer, specializing in non-long-term-evolution (LTE) effects in early-type stars. From 1974 to 1980, he was an Assistant Professor of Astronomy at Boston University. There he taught and worked on the analyses of International Ultraviolet Explorer (IUE) satellite data. Kamp joined the staff at the Jet Propulsion Laboratory/California Institute of Technology (JPL/Caltech) in January 1981, where he remained up until his death.

During Kamp's tenure at JPL/Caltech, he spent two sabbaticals at Oxford University, where he and Fred Taylor modeled near-infrared thermal emission emanating from Venus' deep atmosphere and surface. He also worked on numerous spacecraft projects, including Voyager, Galileo, Viking Orbiter, EPOXI, Rosetta, and JUNO. He was a major contributor to the NIMS effort, particularly in the geometric and photometric aspects of NIMS hyperspectral image cubes.

Kamp was an author or co-author of 190 scientific publications. He received awards from NASA for his work on Cassini, Galileo, Rosetta, and EPOXI, including the NASA Individual Exceptional Service Medal for contributions to Galileo NIMS data processing in October 2003.

— Text courtesy of the Division for Planetary Sciences/S. Gulkis, B. Carlson, and R. Lopes



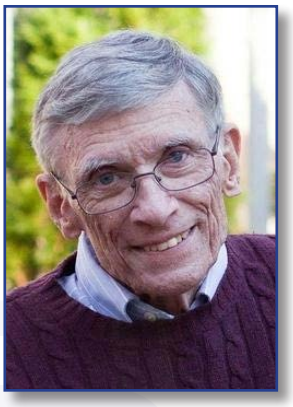
Wubbo Ockels, 1946–2014

Former European Space Agency (ESA) astronaut Wubbo Ockels passed away on May 18, 2014, in a hospital in the Netherlands. Ockels was the second ESA astronaut and the first Dutch citizen to go into space, in 1985. During his Spacelab-D1 mission, he orbited Earth 110 times over 168 hours.

Born in 1946 in Almelo, the Netherlands, Ockels gained a degree in physics and mathematics from the University of Groningen in 1973, and completed his Ph.D. in nuclear physics in 1978. In the same year, he was selected by ESA as one of three science astronauts to train for the Spacelab missions. During the first of these missions, he served as ground-communicator and liaison-scientist for the crew on STS-9.

From 1986, Ockels was based at ESA's Technology Centre (ESTEC) in Noordwijk, the Netherlands, where he supported human spaceflight activities and later became Head of ESA's Education and Outreach Office. During this time he also held a part-time professorship in aerospace at the Delft University of Technology, and in 2003 became full-time professor of Aerospace for Sustainable Engineering and Technology at TU Delft, dealing with the exploitation of alternative sources of energy. His team won the World Solar Challenge in 2001, 2003, 2005, 2007, and 2013 with their Nuna solar-powered car, racing over 3000 kilometers across Australia.

Ockels viewed the fame he received as an astronaut as a responsibility to use for the good of humankind, and throughout his life continued to champion sustainable projects, such as the Ecolution ship, innovation, and working with youth. ESA has lost a fantastic ambassador and a dear friend.



Barney Conrath, 1935–2014

Barney J. Conrath, of Charlottesville, Virginia, passed away peacefully in his sleep at home on Wednesday, April 23, 2014, following a bout with cancer. Conrath was an astrophysicist, working at NASA Goddard Space Flight Center and Cornell University. His studies of planetary atmospheres included experiments on the Voyager 1 and 2 missions, Mars Global Surveyor, and most recently on the NASA/European Space Agency Cassini mission. He was the recipient of numerous awards, including the Kuiper Prize from the Division of Planetary Sciences of the American Astronomical Society in 1996.

Conrath was also an avid amateur fine art black and white photographer. He recently had a showing of his work at the Firefish Gallery in Charlottesville, and was a member of the James River Arts Council in Scottsville, Virginia.

LPI Announces Planetary Science Summer Interns

The Lunar and Planetary Institute (LPI) is pleased to announce the arrival of the 2014 class of the LPI Summer Intern Program in Planetary Science. The LPI's highly competitive intern program offers undergraduates the opportunity to experience cutting-edge research in lunar and planetary science, working one-on-one with scientists at the LPI and the NASA Johnson Space Center (JSC) on a project of current interest in planetary science. This year's program will run from June 2 through August 8. Twelve students were selected from a highly competitive pool of more than 800 applicants.

This year's interns are Eleanor Armstrong, The University of Oxford; Steven Dibb, University of California Santa Cruz; Stefan Farsang, University of St. Andrews; Allison Fox, Indiana University; Timothy Gregory, The University of Manchester; Benjamin Go, University of Chicago; Elise Harrington, Simon Fraser University; Molly Johnson, Winona State University; Kaitlyn McCain, University of Chicago; Jeffrey Murl, University of Hawaii at Monoa; Alyssa Pascuzzo, Smith College; and Zachery Torrano, University of Notre Dame.

For more information about the LPI's intern program, visit *www.lpi.usra.edu/lpiintern*.

Barringer Award Recipients Announced

The Lunar and Planetary Institute (LPI) is pleased to announce the names of the students whose research will be supported by The Barringer Family Fund for Meteorite Impact Research. The 2014 awardees are Elmar Buhl, Albert-Ludwigs-Universität Freiburg, Germany; Anna Chanou, University of Western Ontario, Canada; Agnese Fazio, Università di Pisa, Italy; Erik S. Heider, Auburn University, United States; Pedro E. Montalvo Jiménez, University of Puerto Rico, United States; Mario Mustasaar, University of Tartu, Estonia; and Sarah Simpson, University of Glasgow, United Kingdom.

The Barringer Family Fund for Meteorite Impact Research was established to support field work by eligible students interested in the study of impact cratering processes. The Fund provides a small number of competitive grants each year for support of field research at known or suspected impact sites worldwide. The Barringer Family Fund is a memorial to four of Daniel Moreau Barringer's sons: Brandon, Moreau (or Reau as he was called), Paul, and Richard. As the first person to identify the true origin of the Barringer Meteorite Crater (aka Meteor Crater), Daniel Moreau Barringer instilled a deep interest about the crater and its signficance to his sons. Each of them, in turn, had a lifelong association with the crater and the field of meteoritics from its early beginnings.

In addition to its memorial nature, the Fund also reflects the family's long-standing commitment to responsible stewardship of The Barringer Meteorite Crater and the family's steadfast resolve in maintaining the crater as a unique scientific research and education site. For more information, visit *www.lpi.usra.edu/science/kring/Awards/Barringer_Fund*.

Uwingu Awards Graduate Student Travel Grants to Research Conferences

Uwingu announced on June 3 that it has awarded 11 travel grants to finishing Ph.D. students from both the U.S. and overseas to present their results at research conferences. Winning students were selected from a field of dozens of applications Uwingu received in late April. The travel grants support research topics ranging from martian and lunar science, to astrobiology, to exoplanets. The selected students are Brandi Carrier, Tufts University; Aditya Chopra, Australian National University; Ingrid Daubar, University of Arizona; Catherine Elder, University of Arizona; Ellen Harju, University of California, Los Angeles; Lu Liu, University of Washington; Bo Ma, University of Florida; Johanna Teske, University if Arizona; Jessica Watkins, University of California, Los Angeles; Jennifer Whitten, Brown University; and Mehmet Yesiltas, University of Central Florida.

Uwingu is a small, for-profit company founded by astronomers, planetary scientists, space educators, and former NASA personnel. The mission of Uwingu is to create new ways for people to personally connect with space exploration and astronomy. Through the Uwingu Fund, they raise money to provide grants for space exploration, space research, and space education, ideally providing an additional source of funding for researchers and educators as government budgets shrink. For more information, visit *www.uwingu.com*.

David Black Selected as President and CEO of SETI Institute

Dr. David Black. Credit: SETI Institute.

The SETI Institute in Mountain View, California, has announced the selection of Dr. David Black as its new President and Chief Executive Officer. Black, who is President and CEO Emeritus of the Universities Space Research Association, as well as Visiting Scientist and former Director of the Lunar and Planetary Institute, is a widely recognized researcher in the fields of star and planet formation and the search for exoplanets. Black also served as the Chief Scientist for the Space Station and Deputy Chief for the Space Science Division at NASA Ames Research Center. He has chaired numerous advisory committees for NASA and the National Science Foundation. "The work done at the Institute will inform humanity's understanding of its past, and help point the way to its future," says Black. The SETI Institute provides a focus for studies of some of the more profound questions that humans can ask. For example, how did life come into existence, and is there life on planets orbiting distant stars? "Learning how life originates, or discovering it elsewhere will raise important societal questions," says Black.

While widely known for its expertise in the use of specialized radio antennas to search for signals that would indicate extraterrestrial intelligence, the SETI Institute has a much broader research agenda. More than 75 research scientists lead studies that bear on the search for life, past or present, on Mars or on moons of the outer solar system, as well as the location, composition, and history of asteroids, meteors, and interstellar dust. Institute scientists also investigate the mechanisms of terrestrial life's origins and development. The Institute also hosts the Rings Node of the Planetary Data System, which serves scientists worldwide. Black notes, "With the discovery of hundreds, perhaps thousands, of planets orbiting distant stars, the mission of the SETI Institute is more relevant now than when it began." The Institute is closely involved with data analysis for NASA's Kepler Mission, an exciting effort that has discovered nearly a thousand exoplanets, and yielded our first real understanding of the occurrence and arrangement of planetary systems in other star systems.

Black is assuming leadership of an Institute committed to educational activities to improve the teaching of science, and to increase science literacy among the public. These efforts include outreach programs for the SOFIA and Kepler telescope missions, as well as teacher training, a weekly one-hour science radio program, and the video streaming of colloquia held at the Institute's Mountain View headquarters. The Institute's social media maintains a conversation with a worldwide audience.

The Institute's research agenda emphasizes the nature and distribution of life beyond Earth. It was founded in 1984 by Thomas Pierson, and started with a handful of scientists and a single project. Pierson managed the growing Institute until 2012, at which point he was succeeded by Edna DeVore. Black steps into an organization that has increased significantly in size and scope, and now boasts over 120 employees. For more information, visit *www.seti.org*.

Dr. Linda Shore. Credit: ASP.

Linda Shore Named New Executive Director of the Astronomical Society of the Pacific

The Astronomical Society of the Pacific (ASP) is pleased to announce the appointment of Dr. Linda Shore to the position of Executive Director. Most recently, Shore served as Director of the Teacher Institute at San Francisco's renowned science museum, the Exploratorium. While there she led a staff of scientists and educators, and created nationally recognized teaching programs. She was also responsible for funding development, grant programs, and expanding institutional reach by forging collaborations with national and international museums and science centers. Shore has co-authored Exploratorium science and education books, and written articles about popular science and science education for the public. A native San Franciscan who has spent most of her life in the Bay Area, she holds a Ph.D. in science education from Boston University, and a master's degree in physics and astronomy from San Francisco State University. Shore was also the recipient of a prestigious Smithsonian Pre-doctoral Fellowship to work at the Harvard-Smithsonian Center for Astrophysics, where she developed curriculum and conducted research on astronomy learning for the National Science Foundation funded program, Project STAR *(Science Teaching through its Astronomical Roots)*.

For more information about the ASP, visit *www.astrosociety.org*.

ISON Comet Photography Contest Winners Provide Images from Around the World

National Science Foundation
WHERE DISCOVERIES BEGIN

Seven photographers from around the globe received awards for their stunning images of Comet C/2012 S1 (ISON) at the Northeast Astronomy Forum held at Rockland Community College on April 12. The National Science Foundation's (NSF) Division of Astronomical Sciences, *Astronomy* magazine, and *Discover* magazine co-sponsored the photo contest with three categories for entry: (1) cameras and tripods without the use of tracking or telescopes; (2) piggyback cameras riding atop a telescope or motorized mount; (3) through-the-scope images where the telescope acts as the camera's lens.

The winners in the cameras and tripods category are Atish Aman, Delhi, India, "Comet ISON over Pokhara City, Nepal" (first place) and Barry Burgess, Nova Scotia, Canada, "Comet ISON, Port Medway, Nova Scotia" (second place). In the piggyback cameras category, the winners are John Chumack, Ohio, USA, "Comet ISON Gossamer Tail and Disconnection Event" (first place) and Gaeul Song, Korea, "Mercury and ISON" (second place). In the through-the-scope category, the winners are Damian Peach, Hampshire, UK, "Broom Star" (first place) and Gerald Rhemann, Vienna, Austria, "Comet C/2012 S1 ISON" (second place). The People's Choice award was given to Eric Cardoso, Setúbal, Portugal, "Comet ISON."

"ISON was one of the brightest comets in decades, and millions were captivated last November as this Sun-grazing comet flew dangerously close to the Sun's surface," said Maria Womack, an NSF astronomy division program director. "It was so exciting to cheer with so many others in the world as the comet made its first trip to the inner solar system, which, sadly, it did not survive. Capturing an event like Comet ISON is even more of an achievement, because it was so close to the Sun and visible to the naked eye for such a short time. Photographers like those who did so well in our contest, make sure the rest of us don't miss these special occasions. The pictures are impressive and ethereal — and truly captured the comet's last gasp." In fact, Comet ISON deteriorated to almost nothing after its perihelion, so virtually all submissions were of images prior to that point.

Final judges for the contest included Ann Druyan, an author, Cosmos producer and widow of the late Carl Sagan; Daphne and Tony Hallas, two world renowned astrophotographers; Jon Lomberg, an American space artist and science journalist; and David Malin, a British-Australian astronomer and photographer. The winners will be featured in *Astronomy* magazine's June issue. To see the winning photographs, visit *goo.gl/1dguVF*.

Space Center Houston Director Receives National Museum Award

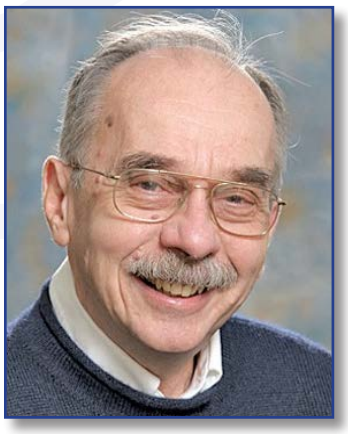
Dr. Melanie Johnson, education director of the nonprofit Space Center Houston, received the 2014 Nancy Hanks Memorial Award for Professional Excellence on Monday, May 19, at the American Alliance of Museums Annual Meeting and Museum (AMM) Expo in Seattle. The award honors a museum professional with less than 10 years of experience in the field. "Dr. Melanie Johnson is living proof of

what museums, committed as they are to our common educational mission, can accomplish," said AAM president Ford W. Bell. "Yet the positive impact museums have everywhere, every day, is due to the people who work in them. I have been privileged to meet innumerable dedicated museum professionals, and Dr. Johnson sets the standard for our entire field."

Dr. Melanie Johnson introduces legendary journalist Dan Rather at a Space Center Houston global science-teacher conference. Johnson was presented with a national award on May 19 from the American Alliance of Museums. Credit: Space Center Houston.

Johnson is an integral part of the team that has transformed Space Center Houston, making it a vibrant, effective, authoritative museum for the history of space flight. And she has done all this with less than five years both on the job and in the museum field. Johnson came to Space Center Houston after a successful career in higher education administration. Her influence extends beyond the museum's walls, as her educational initiatives have made a profound impact on Houston schools. Johnson's mantra — "The art of happiness is serving all people" — has inspired her colleagues at Space Center Houston. Johnson holds a doctorate of education from Texas Southern University and previously worked at The Art Institute of Houston and Galveston (Texas) College.

First given in 1985, the Nancy Hank Memorial Award recognizes a specific achievement that has benefitted either the honoree's home institution or the museum field in general. The cited achievement may be in any area of a museum's operation: administration, exhibitions, education, public relations, registration, collections management, or development. Alternatively, the accomplishment may benefit the museum field generally (for instance, a development plan, membership plan, exhibition design, or collection policy that can serve as a model for other museums). The award commemorates the lifelong support by the late Nancy Hanks of cultural endeavors, and in particular her encouragement of young professionals in the cultural arena.



Dr. John Lewis. Credit: Univ. of Arizona.

John Lewis Wins National Space Society's Space Pioneer Award for Science and Engineering

The National Space Society (NSS) has awarded the 2014 Space Pioneer Award in the Science and Engineering category to Dr. John S. Lewis. This award is in recognition of Lewis' major contributions to the study of the formation and chemistry of asteroids and comets, and his effective work in explaining and promoting both the risks and benefits asteroids offer through his publications. The award was presented to Lewis during the dinner on May 15 as part of its annual conference, the 2014 International Space Development Conference (ISDC).

Lewis is Professor Emeritus of Planetary Sciences and Co-Director of the Space Engineering Research Center at the University of Arizona. After his degree programs at Princeton, Dartmouth, and University of California at San Diego, he taught space science and cosmochemistry at the Massachusetts Institute of Technology, before moving to the University of Arizona. His work on the chemistry and composition of asteroids and comets has resulted in a series of significant scientific publications. He has written 19 books, including graduate and undergraduate texts and popular science books, and has authored more than 150 scientific publications. His clearly written popular books have contributed in a major way to public understanding of space dangers and space resources.

Dr. Shannon W. Lucid. Credit: NASA.

Col. Jerry L. Ross. Credit: NASA.

Lucid and Ross Inducted Into U.S. Astronaut Hall of Fame

Former astronauts Shannon W. Lucid and Jerry L. Ross were inducted into the U.S. Astronaut Hall of Fame in a ceremony held on Saturday, May 3, at NASA's Kennedy Space Center Visitor Complex Space Shuttle Atlantis attraction in Florida.

A veteran of five missions and a member of NASA's first astronaut class to include women, Lucid logged more than 223 days in space. From August 1991 to June 2007, she held the record for the most days in orbit by any woman in the world. Lucid is the only American woman who served onboard the Russian Mir space station, where she lived and worked in 1996 for more than 188 days — the longest stay of any American on that spacecraft.

Ross flew on seven shuttle missions, logged more than 58 days in space, and conducted nine spacewalks totaling 58 hours and 18 minutes. He was the first person to be launched into space seven times. Ross' time spent conducting spacewalks is the all-time second highest among U.S. astronauts.

The induction of Ross and Lucid brings the total number of space exploring Hall of Famers to 87. For more information about the U.S. Astronaut Hall of Fame, visit *www.kennedyspacecenter.com*.

NASA Names Six New Members to Advisory Council

In April, NASA Administrator Charles Bolden announced the appointment of six new members to the NASA Advisory Council (NAC). The group advises NASA's senior leadership on challenges and solutions facing the agency as it unfolds a new era of exploration. The six new members are Wanda Austin, Wayne Hale, Scott Hubbard, Miles O'Brien, Thomas Young, and Kathryn Schmoll. The group has a wide range of expertise in the aerospace field. They are joining NAC Chair Steven Squyres and continuing members Marion Blakey, Kenneth Bowersox, David McComas, William Ballhaus, Charles Kennel (ex officio), and Lester Lyles (ex officio).

Austin is president and chief executive officer of The Aerospace Corporation, a leading architect for the nation's national security space programs. She is internationally recognized for her work in satellite and payload system acquisition, systems engineering, and system simulation and served on President Obama's Review of Human Spaceflight Plans Committee in 2009. Hale is a consultant for Special Aerospace Services of Boulder, Colorado. He retired from NASA in 2010 as the deputy associate administrator of strategic partnerships at the agency's Headquarters in Washington after serving in the senior leadership of the Space Shuttle Program from 2003 to 2008. Hubbard is a consulting professor in the Department of Aeronautics and Astronautics at Stanford University, where he focuses on planetary exploration, especially Mars, and also serves as the director of the Stanford Center of Excellence for Commercial Space Transportation. He is the former director of NASA's Ames Research Center in Moffett Field, California, served on the Columbia Accident Investigation Board, and was director of NASA's Mars Exploration Program.

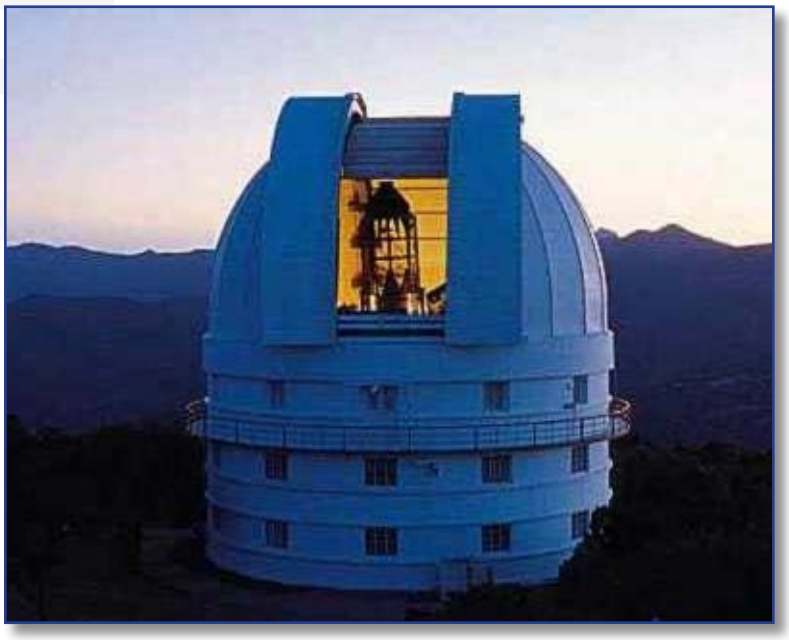
The first meeting of the restructured NASA Advisory Council took place in April at NASA Headquarters in Washington, DC. Standing left to right are Mr. Kenneth Bowersox, Mr. Thomas Young, Mr. Miles O'Brien, Dr. Wanda Austin, Mr. Charles Bolden (NASA Administrator), Ms. Marion Blakey, Gen. Lester Lyles (Ex Officio), Dr. John Holdren (President's Science Advisor and Director, Office of Science and Technology Policy, The White House), Dr. David McComas, Dr. Steven Squyres (Chair), Dr. Charles Kennel (Ex Officio), Dr. William Ballhaus, Mr. Wayne Hale, Ms. Kathryn Schmoll, and Ms. Diane Rausch (Executive Director). Credit: NASA.

O'Brien is a veteran independent journalist who focuses on science, technology, and aerospace. He is the science correspondent for the PBS NewsHour, a producer and director for the PBS science documentary series NOVA, and a correspondent for the PBS documentary series FRONTLINE and the National Science Foundation Science Nation series. He was also the science, environment, and aerospace correspondent and anchor on CNN for 17 years. Young served as executive vice president of Lockheed Martin Corporation and is the former director of NASA's Goddard Space Flight Center in Greenbelt, Maryland, former president and chief operating officer of Martin Marietta, and former chairman of SAIC. He began his NASA career at the Langley Research Center in Virginia, was deputy director of NASA's Ames Research Center, and also was a member of the Lunar Orbiter Project Team, mission director for Program Viking, and director of the Planetary Program at NASA Headquarters. Schmoll is the vice president for finance and administration at the University Corporation for Atmospheric Research in Boulder. She also has served as comptroller for the Environmental Protection Agency and assistant associate administrator in the NASA Headquarters Office of Space Science and Applications, among other NASA positions.

The NAC and its members are assisting the agency on its path to Mars — a stepping-stone approach to exploration that encompasses successful expansion of commercial cargo services to commercial crew, full utilization of the International Space Station until at least 2024, and development of new technologies and the Orion crew vehicle and Space Launch System to travel to an asteroid and the Red Planet. For more information about the NAC, visit *www.nasa.gov/nac*.

McDonald Observatory Celebrates 75 Years of Stargazing with New Exhibit

The Bullock Texas State History Museum and the McDonald Observatory have partnered to produce a new exhibit, "The McDonald Observatory: 75 Years of Stargazing," that opened May 1 in the museum's third-floor Rotunda Gallery, which is free to the public. This anniversary exhibit features large-format graphics of the night sky as seen from one of the best stargazing places on Earth, various pieces of astronomical equipment, and a 1000-pound model of a telescope, among other artifacts and photos.



The 2.1-meter (82-inch) Otto Struve Telescope at the University of Texas McDonald Observatory. Credit: Marty Harris/McDonald Observatory.

The University of Texas at Austin's McDonald Observatory was dedicated on May 5, 1939, and turned 75 this year. The observatory is one of the world's leading centers for astronomical research, teaching, and public education and outreach. Its facilities are located atop Mount Locke and Mount Fowlkes in the Davis Mountains of West Texas, which offer some of the darkest night skies in the continental U.S. The Observatory's administrative offices are on the University of Texas–Austin campus.

Of particular interest in the show is a 1000-pound model of the Otto Struve telescope. The telescope model and other equipment from the observatory will be featured alongside stories of important discoveries, astronomers, and the unique nature of the McDonald Observatory community. Other artifacts in the exhibit include the Carnegie image tube, used to explore whether water could be found on Mars; a *Time* magazine article from the 1940s showcasing the first published color images of Mars made by Dr. G. P. Kuiper with the 82" Otto Struve telescope; and a mirror from the Hobby-Eberly telescope, which has been used to discover planets orbiting other stars and study black holes in distant galaxies, and will soon be used for a study of the mysterious "dark energy" causing the expansion of the universe to speed up over time. For more information, visit *mcdonaldobservatory.org/anniversary*.

BOOKS

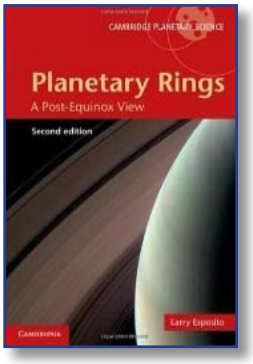
Titan: Interior, Surface, Atmosphere, and Space Environment.

Edited by Ingo Müller-Wodarg, Caitlin A. Griffith, Emmanual Lellouch, and Thomas E. Cravens. Cambridge University Press, 2014, 496 pp., Hardcover, $135.00. *www.cambridge.org*

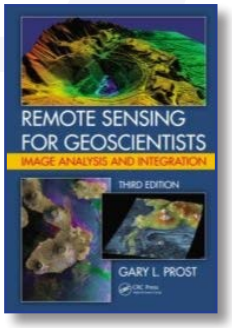
Titan, the largest of Saturn's moons, shares remarkable similarities with Earth. Its thick atmosphere is composed primarily of nitrogen; it features the most complex organic chemistry known outside of Earth and, uniquely, hosts an analog to Earth's hydrological cycle, with methane forming clouds, rain, and seas. Using the latest data from the ongoing Cassini-Huygens missions, laboratory measurements, and numerical simulations, this comprehensive reference examines the physical processes that shape Titan's fascinating atmospheric structure and chemistry, weather, climate, circulation, and surface geology. The text also surveys leading theories about Titan's origin and evolution, and assesses their implications for understanding the formation of other complex planetary bodies. Written by an international team of specialists, chapters offer detailed, comparative treatments of Titan's known properties and discuss the latest frontiers in the Cassini-Huygens mission, offering students and researchers of planetary science, geology, astronomy, and space physics an insightful reference and guide.

Planetary Rings: A Post-Equinox View, Second Edition.

By Larry Esposito. Cambridge University Press, 2014, 258 pp., Hardcover, $120.00. *www.cambridge.org*



Fully updated and expanded, this new edition presents a cutting-edge summary of planetary rings, including results from Cassini's Saturn System, Equinox, and Solstice missions, and the New Horizons flyby of Jupiter. The book introduces basic physical processes and simple mathematical approaches in an accessible manner, including N-body and stochastic models of ring dynamics. Further revised chapters present highlighted topics including Saturn's F ring, Uranus' rings and moons, Neptune's partial rings, dusty rings, and Jupiter's ring-moon system. Cassini results are fully integrated throughout, including new images in color, and a new afterword links ring images in the Cassini "Hall of Fame" gallery to the relevant explanation in the text. An online cache of images and videos from NASA's collection makes it easy to locate relevant and beautiful illustrative materials. This is a key resource for students, researchers, and professionals in planetary science, astronomy, and space-mission research.



Remote Sensing for Geoscientists: Image Analysis and Integration, Third Edition.

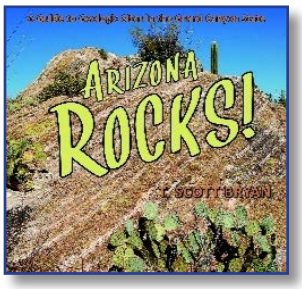
By Gary L. Prost. CRC Press, 2013, Hardcover, 702 pp., $149.95. *www.crcpress.com*

This third edition of the bestselling *Remote Sensing for Geologists: A Guide to Image Interpretation* covers a broad spectrum of geosciences, not just geology; stresses that remote sensing has become more than photointerpretation; and emphasizes integration of multiple remote sensing technologies to solve Earth science problems. The text reviews systems and applications, explains what to

look for when analyzing imagery, and provides abundant case histories to illustrate the integration and application of these tools. There are many examples of geologic mapping on other planets and the Moon highlighting how to analyze planetary surface processes, map stratigraphy, and locate resources. The book also examines remote sensing and the public, geographic information systems and Google Earth, and how imagery is used by the media, in the legal system, in public relations, and by individuals.

Arizona Rocks! A Guide to Geologic Sites in the Grand Canyon State.

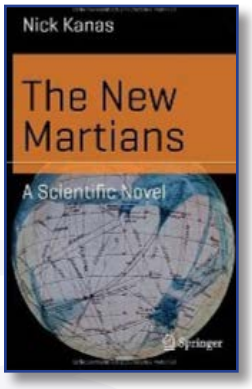
By T. Scott Bryan. Mountain Press Publishing, 2013, 112 pp., Paperback, $18.00. *mountain-press.com*



Arizona is a geologist's playground, with a scientifically intriguing story behind every rocky outcrop, dry playa, and sparkling spring. This book tells the stories of 44 of the best geologic sites in the state, including well-known places such as Barringer Meteorite Crater and Petrified Forest National Park, as well as lesser-known sites, including Hopi Buttes, which formed from steam-driven explosions; Peridot Mesa, where gemstones from Earth's interior are found; and Montezuma Well, a limestone sinkhole with a perennial supply of water. Color photographs compliment the text, and maps help get you where you need to be. This book will introduce readers to some of the most compelling and accessible geologic sites in the state.

The New Martians: A Scientific Novel.

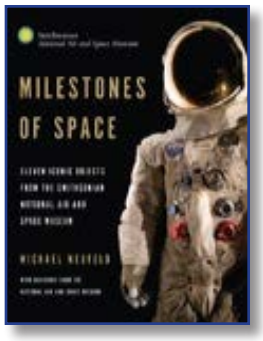
By Nick Kanas. Springer, 2014, 123 pp., Paperback, $19.99. *www.springer.com*



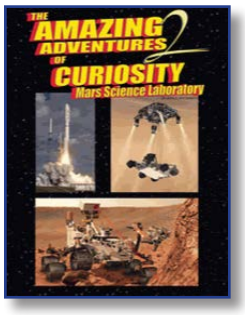
The year is 2035, and the crew from the first expedition to Mars is returning to Earth. The crewmembers are anxious to get home, and ennui pervades the ship. The mood is broken by a series of mysterious events that jeopardize their safety. Someone or something is threatening the crew. Is it an alien being? A psychotic crewmember? A malfunctioning computer? The truth raises questions about the crewmembers' fate and that of the human race. In this novel, the intent is to show real psychological issues that could affect a crew returning from a long-duration mission to Mars. The storyline presents a mystery that keeps the reader guessing, yet the issues at stake are based on the findings from the author's research and other space-related work over the past 40+ years. The novel touches on actual plans being discussed for such an expedition as well as notions involving the search for martian life and panspermia. The underlying science, in particular the psychological, psychiatric, and interpersonal elements, are introduced and discussed by the author in an extensive appendix.

Milestones of Space: Eleven Iconic Objects from the Smithsonian National Air and Space Museum.

Edited by Michael J. Neufeld. Zenith Press, 2014, 176 pp., Hardcover, $30.00. *www.zenithpress.com*



Throughout the whole of human history, across all of Earth's cultures and landscapes, countless individuals have gazed with wonder in the same direction: upward. Getting to space was no easy task, and our curiosity with the surrounding universe has long been a source of earthly pride and competition. At the bottom of this international technological rivalry, though, lies one unifying purpose, which is to understand the impossibly vast heavens. In *Milestones of Space,* Neufeld and select curators of the Smithsonian National Air and Space Museum (NASM) present a gorgeous photographic celebration of some of the most groundbreaking artifacts that played key parts in giving humanity its first steps into the cosmos. Focusing on the most iconic objects and technology — such as Friendship 7, the Lunar Module 2, Neil Armstrong's lunar suit, the Hubble Space Telescope, and Space Shuttle Discovery — this book extensively profiles 11 of the NASM's most important breakthroughs in space technology. The NASM curators feature each object in incredible detail with compelling timelines, sidebars, and captions, and more than 150 archival images that provide new and little-known insights into their development and historical context. We are still a long way from grasping our universe . . . but for now, *Milestones of Space* magnificently commemorates the individuals and inventions that have taken us this far.



The Amazing Adventures 2 of Curiosity Mars Science Laboratory.

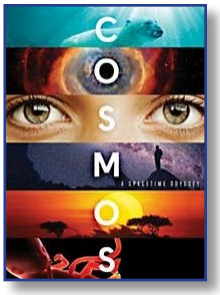
By John C. Wittenberg. Pop Art Printing & Design Studio, 2014, 24 pp., Paperback, $7.75. *www.popartprinting.com*

The exciting adventure of the latest Mars rover, Curiosity Mars Science Laboratory, is presented in a graphic novel format. This Mars rover comic book is a fun and educational look at the newest Mars rover and its mission.

DVD

Cosmos: A Spacetime Odyssey.

Produced by Cosmos Studios and Fuzzy Door Productions, 2014, four disks. $49.98. *shop.nationalgeographic.com*

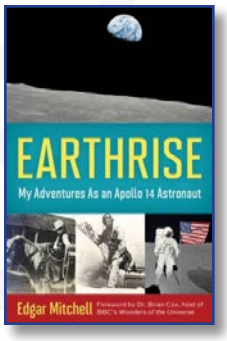


Cosmos: A Spacetime Odyssey, hosted by renowned astrophysicist Neil DeGrasse Tyson, explores how we discovered the laws of nature and found our coordinates in space and time. It brings to life never-before-told stories of the heroic quest for knowledge and transports viewers to new worlds and across the universe for a vision of the cosmos on the grandest scale. *Cosmos* invents new modes of scientific storytelling to reveal the grandeur of the universe and reinvents celebrated elements of the legendary 1980 series hosted by Carl Sagan, including the Cosmic Calendar and the Ship of the Imagination. The most profound scientific concepts are presented with clarity, uniting skepticism and wonder, and weaving rigorous science with the emotional and spiritual into a transcendent experience. Bonus features include "Library of Congress Dedication," "Cosmos at Comic-Con," "Cosmos: A Vision Reborn," and "Interactive Cosmic Calendar."

FOR KIDS!!!

Earthrise: My Adventures as an Apollo 14 Astronaut.

By Edgar Mitchell, with Ellen Mahoney. Chicago Review Press, 2014, 192 pp., Hardcover, $19.95.
www.chicagoreviewpress.com



This is the inspiring and fascinating biography of the sixth man to ever walk on the Moon. Earthrise is a vibrant memoir for young adults featuring the life story of Apollo 14 astronaut Edgar Mitchell. The book focuses on Edgar's amazing journey to the Moon in 1971 and highlights the many steps he took to get there, including growing up as a farm boy on a ranch; living in Roswell, New Mexico, during the alleged UFO crash; graduating from Carnegie Mellon and the Massachusetts Institute of Technology; being a navy combat pilot; and becoming a NASA astronaut. In engaging and suspenseful prose he details his historic flight to the Moon, describing everything from the very practical — eating, sleeping, and going to the bathroom in space — to the metaphysical, such as the life-changing sensation of connectedness to the universe that he felt and that has been described, in varying degrees, by many astronauts. Extensive resources include annotated lists of websites about space, museums and organizations, films and videos, and books for further reading. For ages 12 and up.

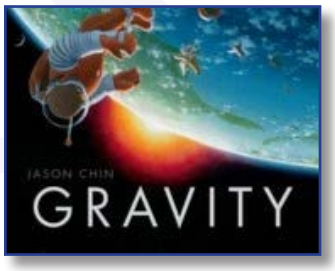
How Many Planets Circle the Sun? And Other Questions About Our Solar System.

By Mary Kay Carson. Sterling Children's Books, 2014, 32 pp., $12.95. *www.sterlingpublishing.com*

Why is there life on Earth? How did Saturn get its rings? Which planet is biggest, which one is hottest — and which has a cloud named Scooter? Take a trip into outer space to learn about the asteroid belt, martian volcanos, dwarf planets, and other fascinating facts about our universe. For ages 6 and up.

Gravity.

By Jason Chin. Roaring Brook Press, 2014, 32 pp., Hardcover, $16.99.
us.macmillan.com



What keeps objects from floating out of your hand? What if your feet drifted away from the ground? What stops everything from floating into space? Gravity. Author Jason Chin takes a complex subject and makes it accessible to young readers in this unusual, innovative, and beautifully illustrated book. For ages 5 to 8.

July

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

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

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

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

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

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

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

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

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

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

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

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

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

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

August

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

4–8 **Saturn in the 21st Century,** Madison, Wisconsin. *http://www.ssec.wisc.edu/meetings/21st_saturn/*

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

6–8 **5th Planetary Crater Consortium Meeting,** Flagstaff, Arizona. *http://www.planetarycraterconsortium.nau.edu*

11–14 **1st LSST Observing Cadences Workshop,** Phoenix, Arizona. *https://project.lsst.org/meetings/lsst2014/*

13–15 **Planetary Rings Workshop,** Boulder, Colorado. *http://lasp.colorado.edu/cassini/PlanetaryRingsWorkshopAug2014.html*

18–22 **19th International Sedimentological Congress of the International Association of Sedimentologists,** Geneva, Switzerland. *http://www.sedimentologists.org/meetings/isc*

20–21 **Solar Wind Interaction with Pluto Workshop,** Boulder, Colorado. *http://lasp.colorado.edu/home/mop/resources/hosted-meetings/swpluto/*

24–28 **Small Bodies Dynamics 2014 (SBD14),** Ubatuba, Brazil. *http://sbd14.sciencesconf.org/*

September

7 **Workshop on Using Radar Imagery for Meteorite Fall Detection and Recovery,** Casablanca, Morocco. *http://www.metsoc2014casablanca.org/workshops.php*

7–12 **European Planetary Science Congress (EPSC 2014),** Cascais, Portugal. *http://www.epsc2014.eu*

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

8–11 **Electrification in Dusty Atmospheres Inside and Outside the Solar System,** Pitlochry, United Kingdom. *http://leap1.sciencesconf.org/*

8–12 **First Astrobiology School at the Observatorio Nacional,** Rio de Janeiro, Brazil. *http://www.on.br/coaa/astrobion2014/indexeng.html*

8–12 **Living Together: Planets, Stellar Binaries and Stars with Planets,** Litomysl, Czech Republic. *http://astro.physics.muni.cz/kopal2014/*

8–12 **Thirty Years of Beta Pic and Debris Disk Studies,** Paris, France. *http://betapic30.sciencesconf.org/*

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*

18–21 **International Meteor Conference 2014,** Giron, France. *http://www.imo.net/*

20–23 **International Conference of Young Astronomers,** Torun, Poland. *http://www.icya.pl/*

22–25 **Exoplanets with JWST–MIRI,** Heidelberg, Germany. *http://www.mpia-hd.mpg.de/exoplanets2014/*

23–27 **National Conference of Astronomers of Serbia,** Belgrade, Serbia. *http://poincare.matf.bg.ac.rs/~astroweb/nkas17/*

24–26 **Joint Workshop on High Pressure, Planetary, and Plasma Physics,** Rostock, Germany. *http://indico.desy.de/conferenceDisplay.py?confId=9404*

29–Oct 3 **65th International Astronautical Congress,** Toronto, Canada. *http://www.iafastro.com/index.php/events/iac/iac-2014*

29–Oct 3 **Dynamical Astronomy in Latin-America,** Santiago, Chile. *http://adela2014.das.uchile.cl*

October

7–10 **Fourth International Workshop on Lunar Cubes,** Mountain View, California. *http://www.lunar-cubes.com/*

13–16 **The 14th European Astrobiology Conference (EANA 2014),** Edinburgh, Scotland. *http://www.astrobiology.ac.uk/eana2014/*

19–22 **GSA Annual Meeting,** Vancouver, British Columbia, Canada. *http://www.geosociety.org/meetings/2014/*

22–24 **Annual Meeting of the Lunar Exploration Analysis Group,** Laurel, Maryland. *http://www.hou.usra.edu/meetings/leag2014/*

23–26 **Solar Eclipse Conference 2014,** Alamagordo, New Mexico. *http://www.eclipse-chasers.com/SEC2014.html*

27–29 **14th ASCE International Conference On Engineering, Science, Construction and Operations In Challenging Environments (Earth and Space 2014),** St. Louis, Missouri. *http://earthspaceconf2014.mst.edu/*

27–31 **19th International Workshop on Laser Ranging,** Greenbelt, Maryland. *http://ilrs.gsfc.nasa.gov/ilrw19/*

27–31 **Réunion des Sciences de la Terre,** Pau, France. *http://rst2014-pau.sciencesconf.org/?lang=en*

29–31 **International Conference on Space Exploration,** Strasbourg, France. *http://space-explo2014.com*

November

1–2 **Workshop on Analytical Methods Applied to Earth and Planetary Sciences,** Sopron, Hungary. *http:/www.hou.usra.edu/meetings/methods2014/*

3–5 **Workshop on Volatiles in the Martian Interior,** Houston, Texas. *http://www.hou.usra.edu/meetings/volatiles2014/*

3–6 **CloudSat and CALIPSO Science Team Meeting,** Greater Washington DC Area. *http://www.hou.usra.edu/meetings/cloudsat2014/*

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

9–14 **46th Meeting of the American Astronomical Society Division for Planetary Sciences (DPS 2014),** Tucson, Arizona. *http://aas.org/meetings/dps46*

16–21 **Triple Evolution and Dynamics in Stellar and Planetary Systems,** Haifa, Israel. *http://trendy-triple.weebly.com/*

18–21 **Star-Planet Interactions and the Habitable Zone,** Saclay, France. *http://irfu.cea.fr/habitability/*

December

4–5 **Hayabusa 2014: Second Symposium of Solar System Materials,** Sagamihara, Japan. *http://hayabusaao.isas.jaxa.jp/symposium/*

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