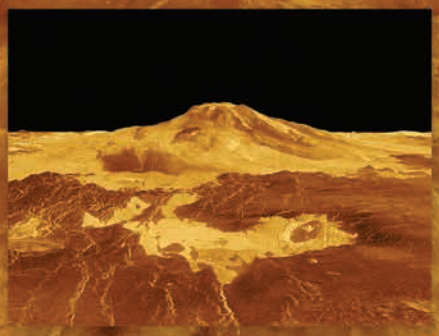
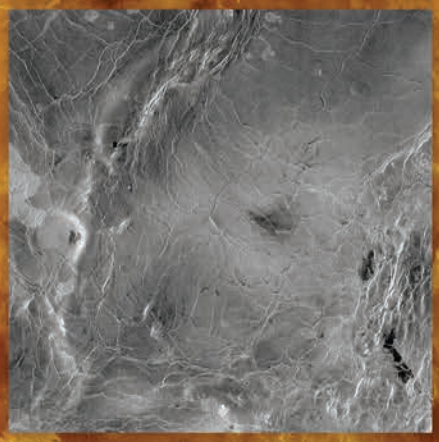
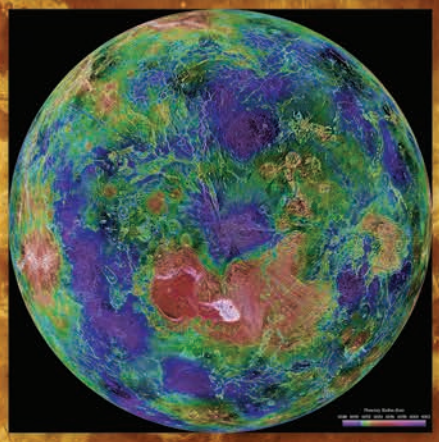
IMPERATIVE: VENUS







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Imperative: Venus

— Virgil L. Sharpton, Lunar and Planetary Institute

Venus and Earth began as twins. Their sizes and densities are nearly identical and they stand out as being considerably more massive than other terrestrial planetary bodies. Formed so close to Earth in the solar nebula, Venus likely has Earth-like proportions of volatiles, refractory elements, and heat-generating radionuclides. Yet the Venus that has been revealed through exploration missions to date is hellishly hot, devoid of oceans, lacking plate tectonics, and bathed in a thick, reactive atmosphere. A less Earth-like environment is hard to imagine.

Venus, Earth, and Mars to scale. Which of our planetary neighbors is most similar to Earth? Hint: It isn't Mars.

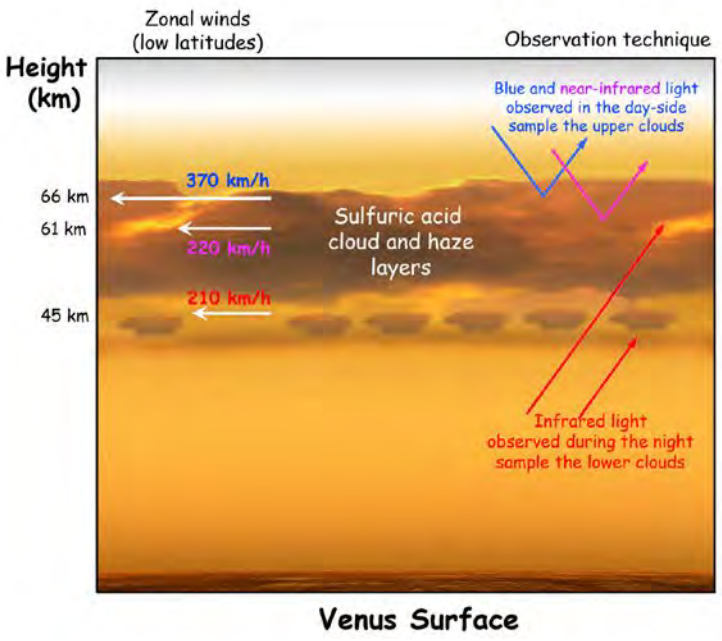
Why and when did Earth's and Venus' evolutionary paths diverge? This fundamental and unresolved question drives the need for vigorous new exploration of Venus. The answer is central to understanding Venus in the context of terrestrial planets and their evolutionary processes. In addition, however, and unlike virtually any other planetary body, Venus could hold 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.

Precisely because it began so like Earth, yet evolved to be so different, Venus is the planet most likely to cast new light on the conditions that determine whether or not a planet evolves habitable environments. NASA's Kepler mission and other concurrent efforts to explore beyond our star system are likely to find Earth-sized planets around Sun-sized stars within a few years. The Venus-Earth comparison will be critical in assessing the likelihood that "Earth-sized" means "Earth-like" for these discoveries.

Exploration of Venus already has shown that planetary mass and distance from the parent star are not sufficient predictors of habitability. Further exploration addressing why and when the evolutionary pathways of Venus and Earth diverged therefore seems essential if we are to accurately gauge the likelihood of distant planets developing and maintaining habitable environments.

Has Venus always been uninhabitable? Or is its current environment a product of evolving exogenic or endogenic conditions? Was Venus' surface ever cool enough to sustain standing water, the coin of the habitability realm? Currently Venus' atmosphere is 4 to 5 orders of magnitude dryer than Earth's. Its atmospheric D/H (the ratio between heavy and light hydrogen), however, is ~150 times Earth's value. This is taken to indicate that a vast amount of water has been lost from Venus and has fueled speculations that Venus may once have held an ancient ocean.

Whether or not any of Venus' water condensed prior to loss, however, depends on outgassing and photolytic loss rates as well as past atmospheric conditions that are poorly constrained. Some theoretical support for a cooler, perhaps habitable ancient Venus comes from the Standard Solar Model, which predicts that the Sun has steadily brightened over its lifetime. This implies that about 4 billion years



Atmospheric layers and wind speeds measured by the VIRTIS instrument onboard ESA's Venus Express. Credit: R. Hueso (Universidad del País Vasco).

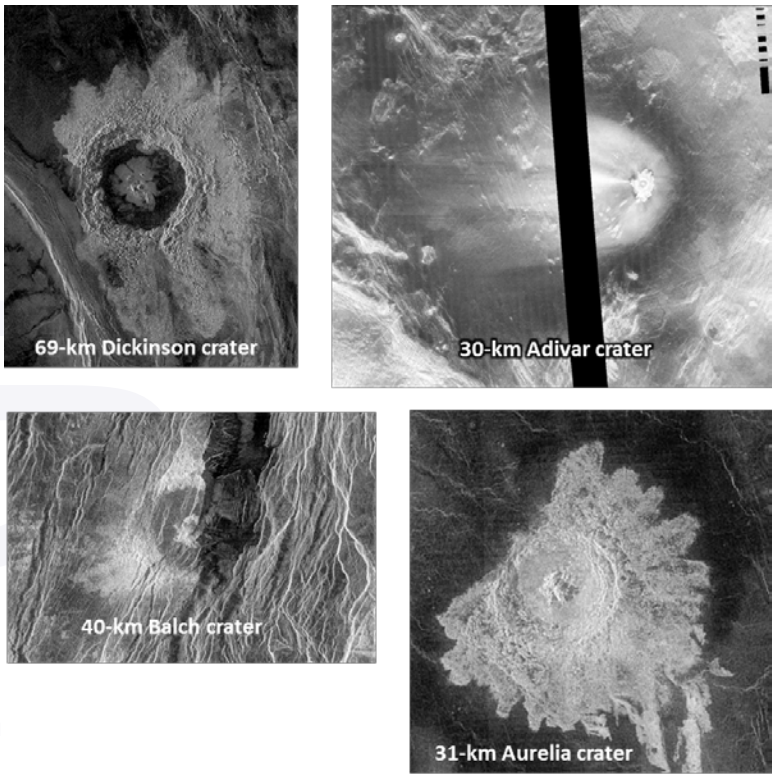
ago — when life was emerging on Earth — the Sun's luminosity was only 70% of its current value. While Mars and perhaps Earth were frozen wastelands, Venus may have been the only place in the solar system where liquid surface water was in abundant, planet-wide supply.

Whether or not Venus was actually cooler early in its history, however, hinges critically on when the current "super greenhouse" began. Without atmospheric effects even today's Venus would have a globally averaged temperature of ~50°C, cool enough to retain liquid water on its surface. The additional greenhouse component due to atmospheric water vapor, however, could overwhelm any earlier mitigating effects of reduced solar luminosity. Atmospheric measurements by themselves cannot constrain the sequence of events needed to reveal whether Venus' water ever resided on its surface or, for that matter, whether Venus was ever fundamentally different than it is today. The only plausible way to retrace critical steps in Venus' evolution is to decipher its geological record in detail.

Magellan mapped Venus from orbit in the early 1990s, and since then only the European Venus Express mission (since 2006) has lingered. These missions revealed a planetary surface dominated by volcanic landforms and extensive lava plains that have been deformed to varying degrees by minor folding and faulting. The quasi-random distribution of impact craters on Venus and the small number that have been conspicuously modified from the outside by volcanic flows have been used to support a model wherein the present volcanic surface of Venus was emplaced rapidly (in as little time as 10 million years) sometime between 1100 and 350 Ma.

This "catastrophic" interpretation of the globally averaged crater retention age of Venus is intriguing but remains controversial. First of all, crater densities are too low to constrain the ages of specific geological units or landforms on Venus. Furthermore, the interpretation that the vast majority of venusian craters are "pristine" has been disputed by studies indicating that craters with smooth, radar dark floor deposits are 150–400 m shallower than those with radar bright (rough) floors. These observations indicate that dark floor craters may have been partially filled by lavas extruded during formation of the surrounding plains. If this is in fact the case, then up to 80% of the existing craters were formed prior to the surrounding plains, and the mean surface age is considerably younger than previously estimated. This scenario would extend almost indefinitely the time interval needed to emplace the assemblage of units and landforms that make up the current surface of Venus.

In point of fact, therefore, current constraints permit a spectrum of scenarios ranging from catastrophic resurfacing of (virtually) the entire planet with little to no subsequent volcanic activity, to more "steady-state" models (where over a longer time span Venus is being resurfaced a small region at a time). Each of these models is defended to a degree far in excess of that justified by current observational constraints.



Venusian impact craters with radar dark floor deposits such as those on the left are typically shallower and older than those with bright floor deposits (right).

This debate — over one of the most fundamental aspects of Venus evolution — is likely to rage until new observations are made that will allow various models to be vigorously tested and either discarded or refined.

The resurfacing style of Venus is not our only enigma. While Venus exhibits extensive rift systems, large areas of heavily deformed terrain (tessera), and even linear mountain belts, there are no morphological or geophysical indicators of a vigorous (i.e., Earth-like) regime of plate tectonics. Instead, the distribution and morphology of Venus' tectonic features and the correlation between its surface topography and gravity anomalies suggest that Venus currently has a thick, dry lithosphere much like smaller "one-plate" planets. How a large planet such as Venus balances its internal heat generation with heat loss through this "stagnant lid" configuration is a major conundrum. Earth loses approximately 70% of its heat by recycling relatively cold, dense lithosphere back into the underlying hot mantle during subduction. Conduction across the thick venusian lithosphere would not be adequate to sustain thermal equilibrium between the interior and surface if abundances and distribution of heat-producing elements are similar to Earth's.

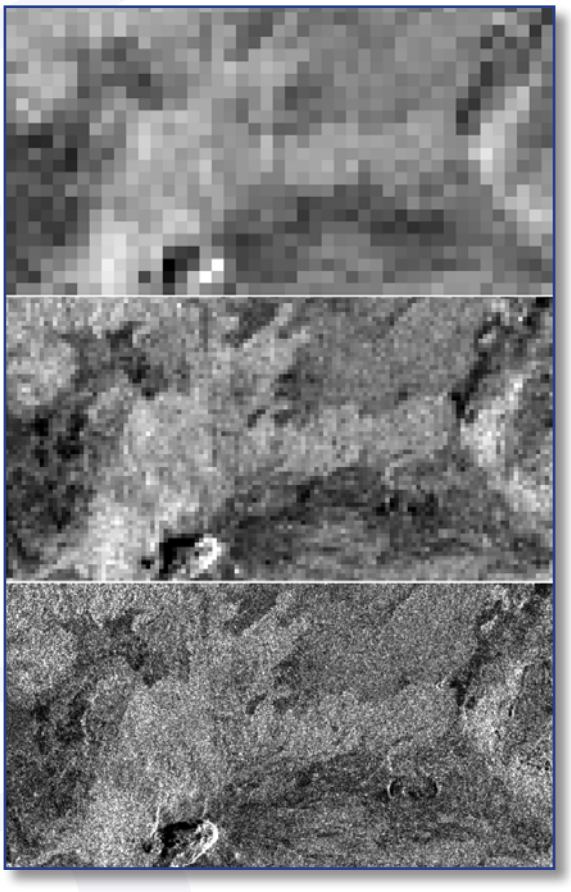
Overlapping, steep-sided "pancake" domes located southeast of Alpha Regio. Morphology and preliminary infrared emissivity suggest these domes contain siliceous materials such as andasite, which on Earth are associated with magmatic water. Magellan image is 150 kilometers wide.

How a solution to this mystery is approached depends on how the average surface age is interpreted. The cornerstone of catastrophists is the episodic-catastrophic resurfacing model wherein internal heat builds to some critical level needed to trigger a global catharsis of lavas, essentially resurfacing the whole planet. The associated cooling of the upper mantle leads to a quasi-stable period of hundreds of millions of years during which the internal heat again increases and the cycle begins anew.

Another related geodynamic model proposes that a transition between "thin-lid" tectonics (with plate

recycling) and a stagnant-lid regime occurred in the recent past (around 300–700 Ma) but does not fully address the issue of long-term internal heat buildup beneath the thickened lithosphere. Whether or not Venus ever developed a regime of plate tectonics is unknown. Improving basic observational constraints holds the only hope of resolving this issue and gaining a more reliable understanding of how internal and external activity are coupled and have evolved.

The two end-member resurfacing models (catastrophic and steady state) predict dramatically different styles and rates for the geological activity that Venus would currently be experiencing. The catastrophic model calls for little volcanic activity (5–30% of Earth's intraplate volcanism), limited to large topographic rises (i.e., only ~10% of the planet's surface). On the other hand, the steady-state model requires high levels of current volcanic activity to balance internal heat generation with surface heat loss, perhaps as much as 80 simultaneous Hawaiian plumes. A new radar mapping mission, returning to Venus several decades after Magellan, should be able to definitively answer the question: How volcanically active is Venus?



Portion of RADARSAT 2 image covering the north flank of the Pu'u O'o vent on the Kilauea volcano, Hawaii, degraded to simulate various radar resolutions. Top: 120-meter resolution cells, simulating the best Magellan quality; middle: 40-meter resolution, representing the typical quality of nominal Earth-orbiting SAR instruments; bottom: 10-meter resolution. Fine-beam modes of operating SARS can reach 1- to 2-meter resolution cells. Image data contributed by MacDonald, Dettwiler and Associates, Ltd.

The most pressing questions in understanding Earth's sister planet require a new mission that significantly improves the imaging and topographic datasets. Current knowledge of Venus is similar to that of Mars in the post-Viking era: While data are of sufficient resolution to permit landscape characterization, major aspects of the planet's history remain unresolved. After Viking, the Mars Orbiter Laser Altimeter (MOLA) onboard Mars Global Surveyor (MGS) acquired global kilometer-scale topography, the Thermal Emission Imaging System (THEMIS) onboard Mars Odyssey and the High Resolution Stereo Camera (HRSC) on Mars Express provided near-global 20 meters/pixel imaging, and MGS' Mars Orbiter Camera (MOC) provided meter-scale imaging of key features. These and other datasets have revolutionized our understanding of the Red Planet a thousandfold. Similarly, MESSENGER and Cassini have radically altered our basic understanding of Mercury and the Saturn system.

Magellan was groundbreaking for its time. In the last 25 years, however, imaging radar technology has made light-year advances over Magellan-era capabilities. Synthetic aperture radar (SAR) instruments operating in Earth's polar orbits routinely acquire broad-swath imagery that has 100 times the spatial resolution of Magellan and with vastly improved sensitivity. By using interferrometric approaches, centimeter-scale changes in surface shape can be detected. Polarimetry further extends SAR's capability to discriminate surface textures that constrain rheological properties and relative ages of rock units. Radar stereogrammetry is widely used to create high-resolution topographic datasets that, among other uses, removes the slant-range distortions in radar images.

Venus holds answers to unresolved questions that are fundamental to understanding habitability and the range of ways in which Earth-sized planets evolve. Modern SAR capabilities offer new and important means to more completely explore and learn from our nearest planetary neighbor. Since the last NASA mission to Venus was launched, 10 missions have been selected to explore Mars and only one to Venus. Given these facts, isn't it time to make a return to Venus the next mission imperative?

About the Author:

Dr. Virgil L. ("Buck") Sharpton is the Associate Director for Science at the Lunar and Planetary Institute (LPI). His planetary research experience includes field validation studies, remote sensing and image processing, synthetic aperture radar (processing and interpretation), geophysical exploration techniques, petrographic microscopy (including u-stage and refractive index measurements), and instrumental geochemical techniques. Sharpton is the founder and former director of the Geographic Information Network of Alaska (GINA), which has attained an international reputation for providing timely and open access to university geospatial data and information services. He has co-authored more than 80 papers in subjects ranging from the morphological analysis of Venus landforms to the role of impact in Earth's biological record. He served on the Executive Committee of the Venus Exploration Advisory Committee (VEXAG) and also served as a Guest Investigator on the Magellan mission team. Sharpton rejoined the staff at the LPI in 2011 to further pursue his interests in planetary research.

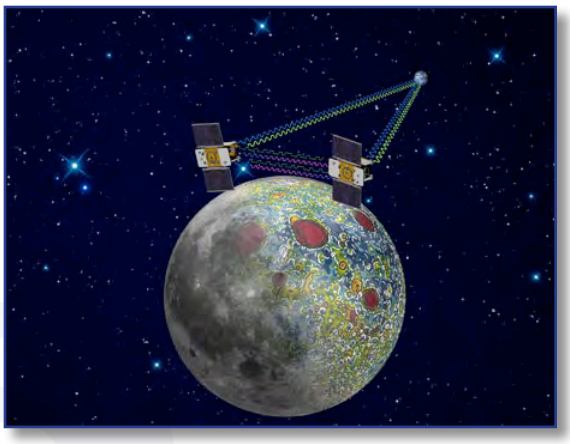
Cover images:

Full page image: This global view of the surface of Venus is centered at 180°E longitude. Magellan synthetic aperture radar mosaics from the first cycle of Magellan mapping are mapped onto a computer-simulated globe to create this image. Data gaps are filled with Pioneer Venus Orbiter data, and simulated color is used to enhance small-scale structure. Simulated hues are based on color images recorded by the Soviet Venera 13 and 14 spacecraft. Credit: NASA.

Inset photo, top: Maat Mons is displayed in this computer-generated three-dimensional perspective of the surface of Venus. The viewpoint is located 634 kilometers (393 miles) north of Maat Mons at an elevation of 3 kilometers (2 miles) above the terrain. The vertical scale in this image is exaggerated 10×. Credit: NASA/JPL.

Inset photo, middle: This compressed resolution radar mosaic from Magellan at 49°N latitude, 165°E longitude shows a 600-kilometer (360 miles) segment of the longest channel discovered on Venus to date. The channel is approximately 1.8 kilometers (1.1 miles) wide. At more than 7000 kilometers (4200 miles) long, it is several hundred kilometers longer than the Nile River, Earth's longest river, thus making it the longest known channel in the solar system. Because both ends of the channel are obscured, however, its original length is unknown. Credit: NASA/JPL.

Inset photo, bottom: The hemispheric view of Venus, as revealed by more than a decade of radar investigations culminating in the 1990–1994 Magellan mission, is centered on the north pole. The Magellan spacecraft imaged more than 98% of Venus at a resolution of about 100 meters; the effective resolution of this image is about 3 kilometers. A mosaic of the Magellan images (most with illumination from the west) forms the image base. Gaps in the Magellan coverage were filled with images from the Earth-based Arecibo radar in a region centered roughly on 0° latitude and longitude, and with a neutral tone elsewhere (primarily near the south pole). The composite image was processed to improve contrast and to emphasize small features, and was color-coded to represent elevation. Credit: NASA/JPL/USGS.



Using a precision formation-flying technique, the twin GRAIL spacecraft mapped the Moon's gravity field, as depicted in this artist's rendering. Credit: NASA/JPL-Caltech.

GRAIL Mission Solves Mystery of Moon's Surface Gravity

NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission has uncovered the origin of massive invisible regions that make the Moon's gravity uneven, a phenomenon that affects the operations of lunar-orbiting spacecraft. Because of GRAIL's findings, spacecraft on missions to other celestial bodies can navigate with greater precision in the future.

GRAIL's twin spacecraft studied the internal structure and composition of the Moon in unprecedented detail for nine months. They pinpointed the locations of large, dense regions called mass concentrations, or mascons, which are characterized by strong gravitational pull. Mascons lurk beneath the lunar surface and cannot be seen by normal optical cameras. GRAIL scientists found the mascons by combining the gravity data from GRAIL with sophisticated computer models of large asteroid impacts and known detail about the geologic evolution of the impact craters. The findings were published in the May 31 edition of the journal *Science*.

"GRAIL data confirm that lunar mascons were generated when large asteroids or comets impacted the ancient Moon, when its interior was much hotter than it is now," said Jay Melosh, a GRAIL co-investigator at Purdue University in West Lafayette, Indiana, and lead author of the paper. "We believe the data from GRAIL show how the Moon's light crust and dense mantle combined with the shock of a large impact to create the distinctive pattern of density anomalies that we recognize as mascons."

The origin of lunar mascons has been a mystery in planetary science since their discovery in 1968 by a team at NASA's Jet Propulsion Laboratory. Researchers generally agree mascons resulted from ancient impacts billions of years ago. It was not clear until now how much of the unseen excess mass resulted from lava filling the crater or iron-rich mantle upwelling to the crust.

On a map of the Moon's gravity field, a mascon appears in a target pattern. The bulls-eye has a gravity surplus. It is surrounded by a ring with a gravity deficit. A ring with a gravity surplus surrounds the bulls-eye and the inner ring. This pattern arises as a natural consequence of crater excavation, collapse, and cooling following an impact. The increase in density and gravitational pull at a mascon's bulls-eye is caused by lunar material melted from the heat of a long-ago asteroid impact.

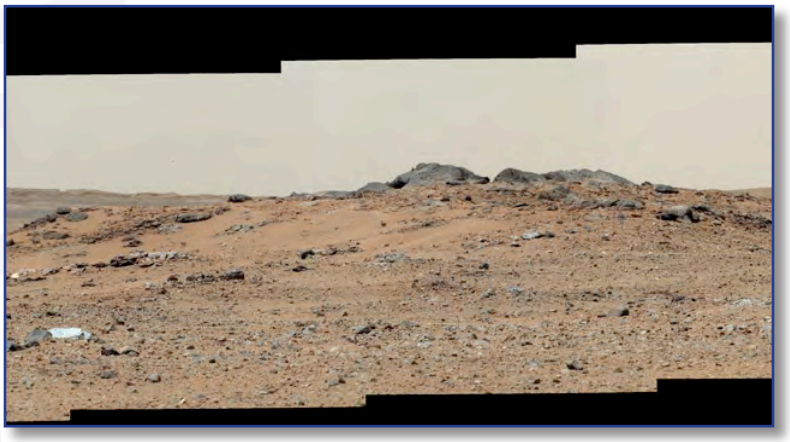
"Knowing about mascons means we finally are beginning to understand the geologic consequences of large impacts," Melosh said. "Our planet suffered similar impacts in its distant past, and understanding mascons may teach us more about the ancient Earth, perhaps about how plate tectonics got started and what created the first ore deposits."

Launched as GRAIL A and GRAIL B in September 2011, the probes, renamed Ebb and Flow, operated in a nearly circular orbit near the poles of the Moon at an altitude of about 34 miles (55 kilometers) until their mission ended in December 2012. The distance between the twin probes changed slightly as they flew over areas of greater and lesser gravity caused by visible features, such as mountains and craters, and by masses hidden beneath the lunar surface.

The first science findings from GRAIL were published in the February 8 issue of *Science*. For more information, visit *www.nasa.gov/grail*.

NASA's Curiosity Celebrates First Anniversary on Mars

NASA's Curiosity rover just marked one year on Mars and has already achieved its main science goal of revealing that ancient Mars could have supported life. The mobile laboratory also is guiding designs for future planetary missions. "Successes of our Curiosity — that dramatic touchdown a year ago and the science findings since then — advance us toward further exploration, including sending humans to an asteroid and Mars," said NASA Administrator Charles Bolden. "Wheel tracks now, will lead to boot prints later."



This scene combines seven images from the telephoto-lens camera on the right side of the Mast Camera (Mastcam) instrument on Curiosity. The component images were taken between 11:39 and 11:43 a.m., local solar time, on the 343rd martian day (sol) of the rover's work on Mars (July 24, 2013). That was shortly before Curiosity's Sol 343 drive of 111 feet (33.7 meters). The rover had driven 205 feet (62.4 meters) on Sol 342 to arrive at the location providing this vista. The center of the scene is toward the southwest. Credit: NASA/JPL-Caltech/Malin Space Science Systems.

After inspiring millions of people worldwide with its successful landing in a crater on the Red Planet on August 5, 2012, PDT (August 6, EDT), Curiosity has provided more than 190 gigabits of data, returned more than 36,700 full images and 35,000 thumbnail images, fired more than 75,000 laser shots to investigate the composition of targets, collected and analyzed sample material from two rocks, and driven more than 1 mile (1.6 kilometers).

Curiosity team members at NASA's Jet Propulsion Laboratory shared remembrances about the dramatic landing night and the overall mission in an event that aired on NASA Television and the agency's website on August 6. The live public event at NASA Headquarters that immediately followed featured NASA officials and crew members onboard the International Space Station as they observed the rover anniversary and discussed how its activities and other robotic projects are helping prepare for a human mission to Mars and an asteroid.

Curiosity, which is the size of a car, has traveled more than 764 yards (699 meters) since leaving a group of science targets where it worked for more than six months. The rover is making its way to the base of Mount Sharp, where it will investigate lower (older) layers of a mountain that rises three miles from the floor of the crater.

NASA's Mars Science Laboratory spacecraft and its unprecedented sky crane landing system placed Curiosity on Mars near the base of Mount Sharp. The mountain has exposed geological layers, including ones identified by Mars orbiters as originating in a wet environment. The rover landed about 1 mile (1.6 kilometers) from the center of that carefully chosen, 12-mile-long (20-kilometer-long) target area. Scientists decided to first investigate closer outcrops where the mission quickly found signs of vigorous ancient stream flow. These were the first streambed pebble deposits ever examined up close on Mars.

Evidence of a past environment well suited to support microbial life came within the first 8 months of the 23-month primary mission from analysis of the first sample material ever collected by drilling into a rock on Mars. "We now know Mars offered favorable conditions for microbial life billions of years ago," said the mission's project scientist, John Grotzinger of the California Institute of Technology in Pasadena.

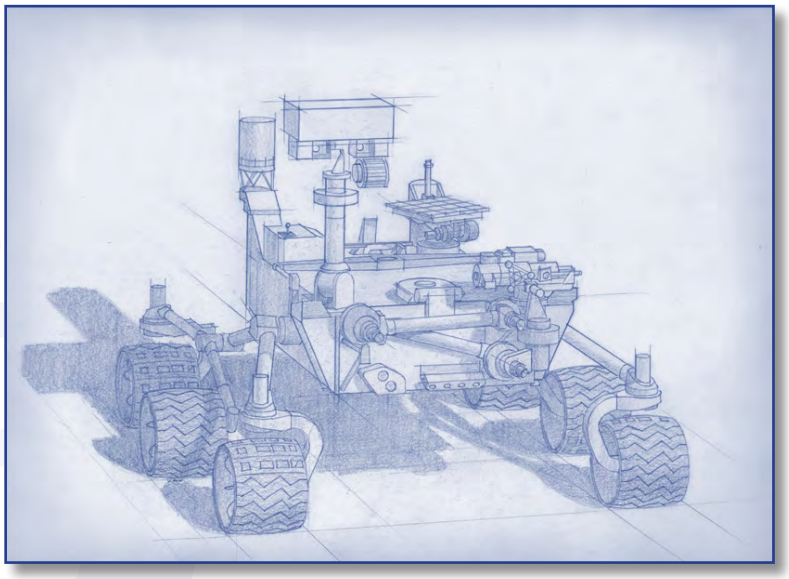
"It has been gratifying to succeed, but that has also whetted our appetites to learn more. We hope those enticing layers at Mount Sharp will preserve a broad diversity of other environmental conditions that could have affected habitability."

The mission measured natural radiation levels on the trip to Mars and is monitoring radiation and weather on the surface of Mars, which will be helpful for designing future human missions to the planet. The Curiosity mission also found evidence that Mars lost most of its original atmosphere through processes that occurred at the top of the atmosphere. NASA's next mission to Mars, Mars Atmosphere and Volatile Evolution (MAVEN), is being prepared for launch in November to study those processes in the upper atmosphere.

To follow the conversation online about Curiosity's first year on Mars, use hashtag #1YearOnMars or follow @NASA and @MarsCuriosity on Twitter. A movie made with Hazard-Avoidance Camera images from Curiosity's first year, entitled "Twelve Months in Two Minutes," is available at *mars.nasa.gov/msl/1yearin2mins*. For more information about the mission, visit *www.nasa.gov/msl* and *mars.jpl.nasa.gov/msl*.

Science Team Outlines Goals for NASA's 2020 Mars Rover

The rover NASA will send to Mars in 2020 should look for signs of past life, collect samples for possible future return to Earth, and demonstrate technology for future human exploration of the Red Planet, according to a report provided to the agency. The 154-page document was prepared by the Mars 2020 Science Definition Team, which NASA appointed in January to outline scientific objectives for the mission. The team, composed of 19 scientists and engineers from universities and research organizations, proposed a mission concept that could accomplish several high-priority planetary science goals and be a major step in meeting President Obama's challenge to send humans to Mars in the 2030s.



Planning for NASA's 2020 Mars rover envisions a basic structure that capitalizes on the design and engineering work done for the NASA rover Curiosity, which landed on Mars in 2012, but with new science instruments selected through competition for accomplishing different science objectives. Credit: NASA/JPL-Caltech.

"Crafting the science and exploration goals is a crucial milestone in preparing for our next major Mars mission," said John Grunsfeld, NASA's associate administrator for science in Washington. "The objectives determined by NASA with the input from this team will become the basis later this year for soliciting proposals to provide instruments to be part of the science payload on this exciting step in Mars exploration."

NASA will conduct an open competition for the payload and science instruments. They will be placed on a rover similar to Curiosity, which landed on Mars last year. Using Curiosity's design will help minimize mission costs and risks and deliver a rover that can accomplish the mission objectives. The 2020 mission proposed by the Science Definition Team would build upon the accomplishments of Curiosity and other Mars missions.

The Spirit and Opportunity rovers, along with several orbiters, found evidence Mars has a watery history. Curiosity recently confirmed that past environmental conditions on Mars could have supported living microbes. According to the Science Definition Team, looking for signs of past life is the next logical step.

The team's report details how the rover would use its instruments for visual, mineralogical, and chemical analysis down to microscopic scale to understand the environment around its landing site and identify biosignatures, or features in the rocks and soil that could have been formed biologically. "The Mars 2020 mission concept does not presume that life ever existed on Mars," said Jack Mustard, chairman of the Science Definition Team and a professor at the Geological Sciences at Brown University in Providence, Rhode Island. "However, given the recent Curiosity findings, past martian life seems possible, and we should begin the difficult endeavor of seeking the signs of life. No matter what we learn, we would make significant progress in understanding the circumstances of early life existing on Earth and the possibilities of extraterrestrial life."

The measurements needed to explore a site on Mars to interpret ancient habitability and the potential for preserved biosignatures are identical to those needed to select and cache samples for future return to Earth. The Science Definition Team is proposing the rover collect and package as many as 31 samples of rock cores and soil for a later mission to bring back for more definitive analysis in laboratories on Earth. The science conducted by the rover's instruments would expand our knowledge of Mars and provide the context needed to make wise decisions about whether to return the samples to Earth.

"The Mars 2020 mission will provide a unique capability to address the major questions of habitability and life in the solar system," said Jim Green, director of NASA's Planetary Science Division in Washington. "This mission represents a major step toward creating high-value sampling and interrogation methods, as part of a broader strategy for sample returns by planetary missions."

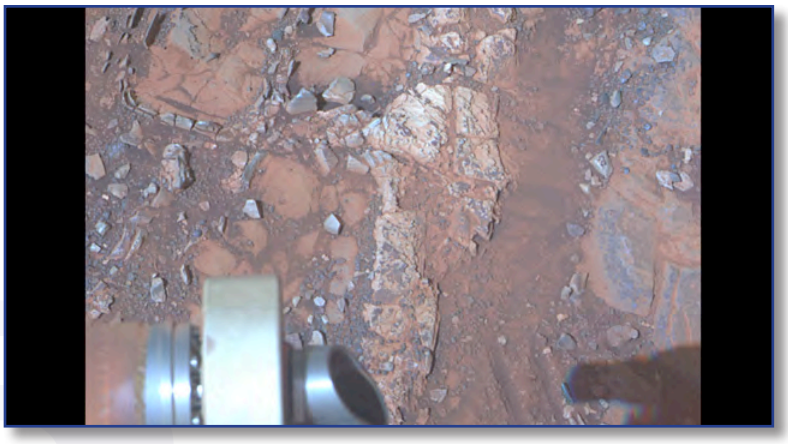
Samples collected and analyzed by the rover will help inform future human exploration missions to Mars. The rover could make measurements and technology demonstrations to help designers of a human expedition understand any hazards posed by martian dust and demonstrate how to collect carbon dioxide, which could be a resource for making oxygen and rocket fuel. Improved precision landing technology that enhances the scientific value of robotic missions also will be critical for eventual human exploration on the surface.

For more information, visit *mars.jpl.nasa.gov/m2020* and *www.nasa.gov/mars*.

Mars Rover Opportunity Examines Clay Clues in Rock

NASA's senior Mars rover, Opportunity, is driving to a new study area after a dramatic finish to 20 months on "Cape York" with examination of a rock intensely altered by water. The fractured rock, called "Esperance," provides evidence about a wet ancient environment possibly favorable for life. The mission's principal investigator, Steve Squyres of Cornell University, said, "Esperance was so important, we committed several weeks to getting this one measurement of it, even though we knew the clock was ticking." The mission's engineers at NASA's Jet Propulsion Laboratory (JPL) had set this week as a deadline for starting a drive toward "Solander Point," where the team plans to keep Opportunity working during its next martian winter.

"What's so special about Esperance is that there was enough water not only for reactions that produced clay minerals, but also enough to flush out ions set loose by those reactions, so that Opportunity can clearly see the alteration," said Scott McLennan of the State University of New York, Stony Brook, a long-term planner for Opportunity's science team. This rock's composition is unlike any other



The pale rock in the upper center of this image, about the size of a human forearm, includes a target called "Esperance," which was inspected by NASA's Mars Exploration Rover Opportunity. Data from the rover's alpha particle X-ray spectrometer (APXS) indicate that Esperance's composition is higher in aluminum and silica, and lower in calcium and iron, than other rocks Opportunity has examined in more than nine years on Mars. Preliminary interpretation points to clay mineral content due to intensive alteration by water. Credit: NASA/JPL-Caltech/Cornell/Arizona State Univ.

Opportunity has investigated during nine years on Mars — higher in aluminum and silica, lower in calcium and iron.

The next destination, Solander Point, and the area Opportunity is leaving, Cape York, are both segments of the rim of Endeavour Crater, which spans 14 miles (22 kilometers) across. The planned driving route to Solander Point is about 1.4 miles (2.2 kilometers). Cape York has been Opportunity's home since the rover arrived at the western edge of Endeavour in mid-2011 after a two-year trek from a smaller crater.

"Based on our current solar-array dust models, we intend to reach an area of 15° northerly tilt before Opportunity's sixth martian winter," said JPL's Scott Lever, mission manager. "Solander Point gives us that tilt and may allow us to move around quite a bit for winter science observations." Northerly tilt increases output from the rover's solar panels during southern-hemisphere winter. Daily sunshine for Opportunity will reach winter minimum in February 2014. The rover needs to be on a favorable slope well before then.

The first drive away from Esperance covered 81.7 feet (24.9 meters) on May 14. Three days earlier, Opportunity finished exposing a patch of the rock's interior with the rock abrasion tool. The team used a camera and spectrometer on the robotic arm to examine Esperance. The team identified Esperance while exploring a portion of Cape York where the Compact Reconnaissance Spectrometer for Mars (CRISM) on NASA's Mars Reconnaissance Orbiter had detected a clay mineral. Clays typically form in wet environments that are not harshly acidic. For years, Opportunity had been finding evidence for ancient wet environments that were very acidic. The CRISM findings prompted the rover team to investigate the area where clay had been detected from orbit. There, they found an outcrop called "Whitewater Lake," containing a small amount of clay from alteration by exposure to water.

"There appears to have been extensive, but weak, alteration of Whitewater Lake, but intense alteration of Esperance along fractures that provided conduits for fluid flow," Squyres said. "Water that moved through fractures during this rock's history would have provided more favorable conditions for biology than any other wet environment recorded in rocks Opportunity has seen."

NASA's Mars Exploration Rover Project launched Opportunity to Mars on July 7, 2003, about a month after its twin rover, Spirit. Both were sent for three-month prime missions to study the history of wet environments on ancient Mars and continued working in extended missions. Spirit ceased operations in 2010. For more information, visit *www.nasa.gov/rovers* and *marsrovers.jpl.nasa.gov*.

NASA's Mars Atmosphere and Volatiles Evolution (MAVEN) spacecraft is seen inside the Payload Hazardous Servicing Facility on Aug. 3. 2013 at the agency's Kennedy Space Center in Florida. MAVEN will be prepared inside the facility for its scheduled November launch to Mars.

NASA Begins Launch Preparations for Next Mars Mission

NASA's next spacecraft going to Mars arrived Friday, August 2, at the agency's Kennedy Space Center in Florida, and is now perched in a cleanroom to begin final preparations for its November launch. The Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft is undergoing detailed testing and fueling prior to being moved to its launch pad. The mission has a 20-day launch period that opens November 18. The spacecraft will conduct the first mission dedicated to surveying the upper atmosphere of Mars. Scientists expect to obtain unprecedented data that will help them understand how the loss of atmospheric gas to space may have played a part in changing the planet's climate.

"We're excited and proud to ship the spacecraft right on schedule," said David Mitchell, MAVEN project manager at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "But more critical milestones lie ahead before we accomplish our mission of collecting science data from Mars. I firmly believe the team is up to the task. Now we begin the final push to launch."

Over the weekend that followed, the team confirmed the spacecraft arrived in good condition. They removed the spacecraft from the shipping container and secured it to a rotation fixture in the cleanroom. In the next week, the team reassembled components previously removed for transport. Further checks prior to launch will include software tests, spin balance tests, and test deployments of the spacecraft's solar panels and booms. "It's always a mix of excitement and stress when you ship a spacecraft down to the launch site," said Guy Beutelschies, MAVEN program manager at Lockheed Martin Space Systems in Littleton, Colorado, the company that designed and built the spacecraft and is responsible for testing, launch processing, and mission operations. "It's similar to moving your children to college after high school graduation. You're proud of the hard work to get to this point, but you know they still need some help before they're ready to be on their own."

Previous Mars missions detected energetic solar fields and particles that could drive atmospheric gases away from Mars. Unlike Earth, Mars does not have a planet-wide magnetic field that would deflect these solar winds. As a result, these winds may have stripped away much of Mars' atmosphere. MAVEN's data will help scientists reconstruct the planet's past climate. Scientists will use MAVEN data to project how Mars became the cold, dusty desert planet we see today. The planned one-year mission begins with the spacecraft entering the Red Planet's orbit in September 2014.

"MAVEN is not going to detect life," said Bruce Jakosky, planetary scientist at the University of Colorado Boulder and MAVEN's principal investigator. "But it will help us understand the climate history, which is the history of its habitability." Jakosky is based at the University of Colorado Laboratory for Atmospheric and Space Physics in Boulder. The university provides science instruments and leads science operations, education and public outreach.

To learn more about the MAVEN mission, visit *www.nasa.gov/maven*.

Marks on Martian Dunes May Be Tracks of Dry-Ice Sleds

NASA research indicates hunks of frozen carbon dioxide — dry ice — may glide down some martian sand dunes on cushions of gas similar to miniature hovercraft, plowing furrows as they go. Researchers deduced this process could explain one enigmatic class of gullies seen on martian sand dunes by examining images from NASA's Mars Reconnaissance Orbiter (MRO) and performing experiments on sand dunes in Utah and California. "I have always dreamed of going to Mars," said Serina Diniega, a planetary scientist at NASA's Jet Propulsion Laboratory, and lead author of a report published online by the journal *Icarus*. "Now I dream of snowboarding down a martian sand dune on a block of dry ice."

Several types of downhill flow features have been observed on Mars. This image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter is an example of a type called "linear gullies." Credit: NASA/JPL-Caltech/Univ. of Arizona.

The hillside grooves on Mars, called linear gullies, show relatively constant width — up to a few yards, or meters, across — with raised banks or levees along the sides. Unlike gullies caused by water flows on Earth and possibly on Mars, they do not have aprons of debris at the downhill end of the gully. Instead, many have pits at the downhill end. "In debris flows, you have water carrying sediment downhill, and the material eroded from the top is carried to the bottom and deposited as a fan-shaped apron," said Diniega. "In the linear gullies, you're not transporting material. You're carving out a groove, pushing material to the sides."

Images from MRO's High Resolution Imaging Science Experiment (HiRISE) camera show sand dunes with linear gullies covered by carbon-dioxide frost during the martian winter. The location of the linear gullies is on dunes that spend the martian winter covered by carbon-dioxide frost. By comparing before-and-after images from different seasons, researchers determined that the grooves are formed during early spring. Some images have even caught bright objects in the gullies.

Scientists theorize the bright objects are pieces of dry ice that have broken away from points higher on the slope. According to the new hypothesis, the pits could result from the blocks of dry ice completely sublimating away into carbon-dioxide gas after they have stopped traveling. "Linear gullies don't look like gullies on Earth or other gullies on Mars, and this process wouldn't happen on Earth," said Diniega. "You don't get blocks of dry ice on Earth unless you go buy them."

That is exactly what report co-author Candice Hansen, of the Planetary Science Institute in Tucson, Arizona, did. Hansen has studied other effects of seasonal carbon-dioxide ice on Mars, such as spider-shaped features that result from explosive release of carbon-dioxide gas trapped beneath a sheet of dry ice as the underside of the sheet thaws in spring. She suspected a role for dry ice in forming linear gullies, so she bought some slabs of dry ice at a supermarket and slid them down sand dunes. That day and in several later experiments, gaseous carbon dioxide from the thawing ice maintained a lubricating layer under the slab and also pushed sand aside into small levees as the slabs glided down even low-angle slopes.

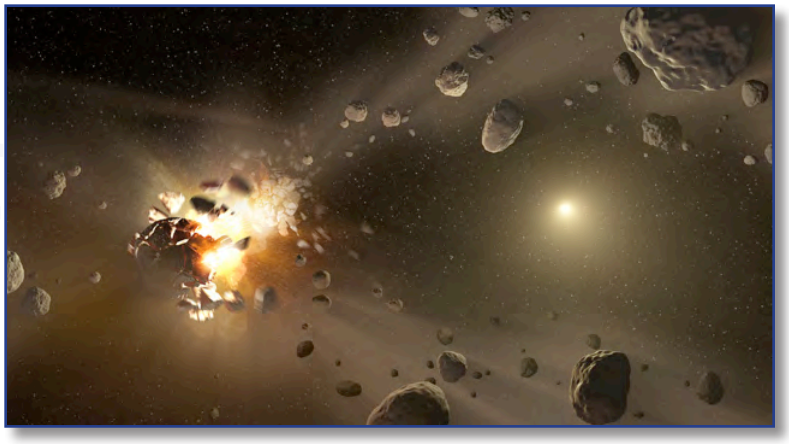
The outdoor tests did not simulate martian temperature and pressure, but calculations indicate the dry ice would act similarly in early martian spring where the linear gullies form. Although water ice, too, can sublimate directly to gas under some martian conditions, it would stay frozen at the temperatures at which

these gullies form, the researchers calculate. “MRO is showing that Mars is a very active planet,” Hansen said. “Some of the processes we see on Mars are like processes on Earth, but this one is in the category of uniquely martian.”

To see images of the linear gullies and obtain more information about MRO, visit *www.nasa.gov/mro*. For more about HiRISE, visit *hirise.lpl.arizona.edu*.

NASA’s WISE Mission Finds Lost Asteroid Family Members

Data from NASA’s Wide-field Infrared Survey Explorer (WISE) have led to a new and improved family tree for asteroids in the main belt between Mars and Jupiter. Astronomers used millions of infrared snapshots from the asteroid-hunting portion of the WISE all-sky survey, called NEOWISE, to identify 28 new asteroid families. The snapshots also helped place thousands of previously hidden and uncategorized asteroids into families for the first time. The findings are a critical step in understanding the origins of asteroid families, and the collisions thought to have created these rocky clans.



This artists concept shows how families of asteroids are created. Over the history of our solar system, catastrophic collisions between asteroids located in the belt between Mars and Jupiter have formed families of objects on similar orbits around the Sun. Credit: NASA/JPL-Caltech.

“NEOWISE has given us the data for a much more detailed look at the evolution of asteroids throughout the solar system,” said Lindley Johnson, the program executive for the Near-Earth Object Observation Program at NASA Headquarters in Washington. “This will help us trace the NEOs back to their sources and understand how some of them have migrated to orbits hazardous to the Earth.”

The main asteroid belt is a major source of near-Earth objects (NEOs), which are those asteroids and comets that come within 28 million miles (45 million kilometers) of Earth’s path around the Sun. Some NEOs start out in stable orbits in the main asteroid belt, until a collision or gravitational disturbance flings them inward like flippers in a game of pinball. The NEOWISE team looked at about 120,000 main belt asteroids out of the approximately 600,000 known. They found that about 38,000 of these objects, roughly one-third of the observed population, could be assigned to 76 families, 28 of which are new. In addition, some asteroids thought to belong to a particular family were reclassified.

An asteroid family is formed when a collision breaks apart a large parent body into fragments of various sizes. Some collisions leave giant craters. For example, the asteroid Vesta’s southern hemisphere was excavated by two large impacts. Other smash-ups are catastrophic, shattering an object into numerous fragments, as was the case with the Eos asteroid family. The cast-off pieces move together in packs, traveling on the same path around the Sun, but over time the pieces become more and more spread out.

Previous knowledge of asteroid family lineages comes from observations of their orbits. NEOWISE also looked at the asteroids’ reflectivity to identify family members. Asteroids in the same family generally have similar mineral composition and reflect similar amounts of light. Some families consist of darker-colored, or duller, asteroids, while others are made up of lighter-colored, or shinier, rocks. It is difficult to distinguish

between dark and light asteroids in visible light. A large, dull asteroid can appear the same as a small, shiny one. The dark asteroid reflects less light but has more total surface area, so it appears brighter.

NEOWISE could distinguish between the dark and light asteroids because it could detect infrared light, which reveals the heat of an object. The larger the object, the more heat it gives off. When the size of an asteroid can be measured, its true reflective properties can be determined, and a group of asteroids once thought to belong to a single family circling the Sun in a similar orbit can be sorted into distinct families.

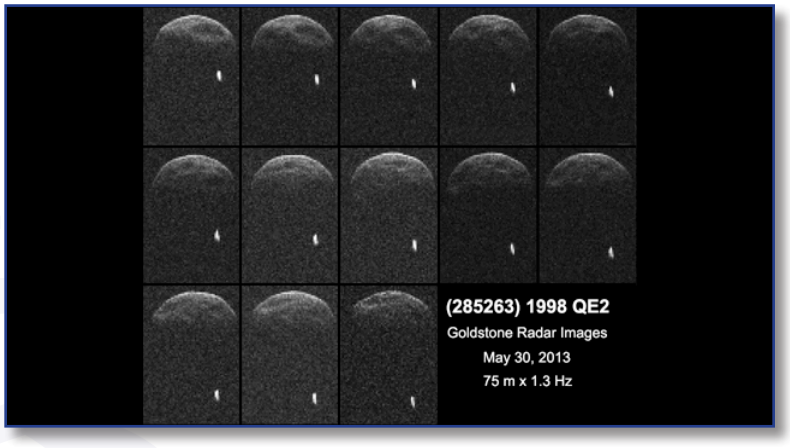
"We're separating zebras from the gazelles," said Joseph Masiero of NASA's Jet Propulsion Laboratory in Pasadena, California, who is lead author of a report on the new study that appears in the *Astrophysical Journal*. "Before, family members were harder to tell apart because they were traveling in nearby packs. But now we have a better idea of which asteroid belongs to which family." The next step for the team is to learn more about the original parent bodies that spawned the families.

More information about the mission is available at *www.nasa.gov/wise*.

NASA Radar Reveals Near-Earth Asteroid Has Its Own Moon

A sequence of radar images of asteroid 1998 QE2 was obtained on the evening of May 29, 2013, by NASA scientists using the 70-meter (230-foot) Deep Space Network antenna at Goldstone, California, when the asteroid was about 6 million kilometers (3.75 million miles) from Earth, which is 15.6 lunar distances.

The radar imagery revealed that 1998 QE2 is a binary asteroid. In the near-Earth population, about 16% of asteroids that are about 200 meters (655 feet) or larger are binary or triple systems. Radar images suggest that the main body, or primary, is approximately 2.7 kilometers (1.7 miles) in diameter and has a rotation period of less than four hours. Also revealed in the radar imagery of 1998 QE2 are several dark surface features that suggest large concavities. The preliminary estimate for the size of the asteroid's satellite, or moon, is approximately 600 meters (2000 feet) wide. The radar collage covers a little bit more than two hours. The radar observations were led by scientist Marina Brozovic of NASA's Jet Propulsion Laboratory.



First radar images of asteroid 1998 QE2 were obtained when the asteroid was about 6 million kilometers (3.75 million miles) from Earth. The small white dot at lower right is the moon, or satellite, orbiting asteroid 1998 QE2. Credit: NASA/JPL-Caltech/GSSR.

The closest approach of the asteroid occurred on May 31 at 1:59 p.m. Pacific (4:59 p.m. Eastern/20:59 UTC), when the asteroid was no closer than about 5.8 million kilometers (3.6 million miles), or about 15 times the distance between Earth and the Moon. This is the closest approach the asteroid will make to Earth for at least the next two centuries. Asteroid 1998 QE2 was discovered on August 19, 1998, by the Massachusetts Institute of Technology Lincoln Near Earth Asteroid Research (LINEAR) program near Socorro, New Mexico.

The resolution of these initial images of 1998 QE2 is approximately 75 meters (250 feet) per pixel. Between May 30 and June 9, radar astronomers using NASA's 70-meter-wide (230 feet) Deep Space

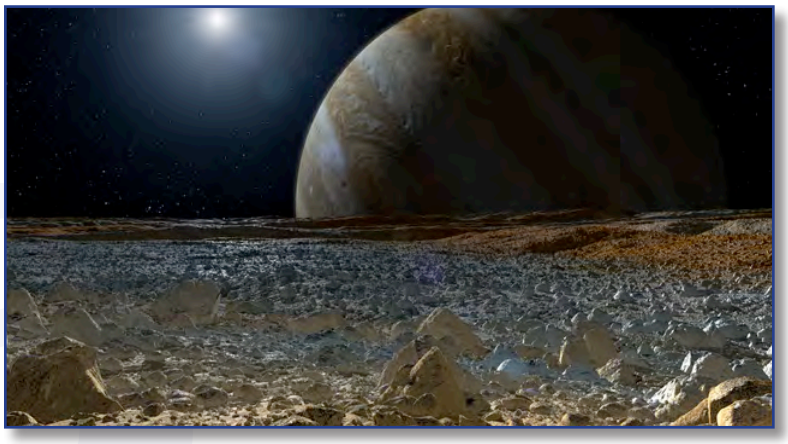
Network antenna at Goldstone, California, and the Arecibo Observatory in Puerto Rico performed an extensive campaign of observations on asteroid 1998 QE2. The two telescopes have complementary imaging capabilities that enabled astronomers to learn as much as possible about the asteroid during its brief visit near Earth.

Radar is a powerful technique for studying an asteroid's size, shape, rotation state, surface features, and surface roughness, and for improving the calculation of asteroid orbits. Radar measurements of asteroid distances and velocities often enable computation of asteroid orbits much further into the future than if radar observations weren't available.

NASA places a high priority on tracking asteroids and protecting our home planet from them. In fact, the United States has the most robust and productive survey and detection program for discovering near-Earth objects (NEOs). To date, U.S. assets have discovered more than 98% of the known NEOs. In 2012, the NEO budget was increased from $6 million to $20 million. Literally dozens of people are involved with some aspect of NEO research across NASA and its centers. Moreover, there are many more people involved in researching and understanding the nature of asteroids and comets, including those objects that come close to Earth, plus those who are trying to find and track them in the first place.

In 2016, NASA will launch a robotic probe to one of the most potentially hazardous of the known NEOs. The OSIRIS-REx mission to asteroid (101955) Bennu will be a pathfinder for future spacecraft designed to perform reconnaissance on any newly discovered threatening objects. Aside from monitoring potential threats, the study of asteroids and comets enables a valuable opportunity to learn more about the origins of our solar system, the source of water on Earth, and even the origin of organic molecules that lead to the development of life.

More information about asteroid radar research is at *echo.jpl.nasa.gov*. More information about the Deep Space Network is at *deepspace.jpl.nasa.gov/dsn*.



This artist's concept shows a simulated view from the surface of Jupiter's moon Europa. Europa's potentially rough, icy surface, tinged with reddish areas that scientists hope to learn more about, can be seen in the foreground. The giant planet Jupiter looms over the horizon. Credit: NASA/JPL-Caltech.

If We Landed on Europa, What Would We Want to Know?

Most of what scientists know of Jupiter's moon Europa they have gleaned from a dozen or so close flybys from NASA's Voyager 2 spacecraft in 1979 and NASA's Galileo spacecraft in the mid-to-late 1990s. Even in these fleeting, paparazzi-like encounters, scientists have seen a fractured, ice-covered world with tantalizing signs of a liquid water ocean under its surface. Such an environment could potentially be a hospitable home for microbial life. But what if we got to land on Europa's surface and conduct something along the lines of a more in-depth interview? What would scientists ask? A new study in the journal *Astrobiology* authored by a NASA-appointed science definition team lays out their consensus on the most important questions to address.

"If one day humans send a robotic lander to the surface of Europa, we need to know what to look for and what tools it should carry," said Robert Pappalardo, the study's lead author, based at NASA's Jet Propulsion Laboratory. "There is still a lot of preparation that is needed before we could land on Europa, but studies like these will help us focus on the technologies required to get us there, and on the data needed to help us scout out possible landing locations. Europa is the most likely place in our solar system beyond Earth to have life today, and a landed mission would be the best way to search for signs of life."

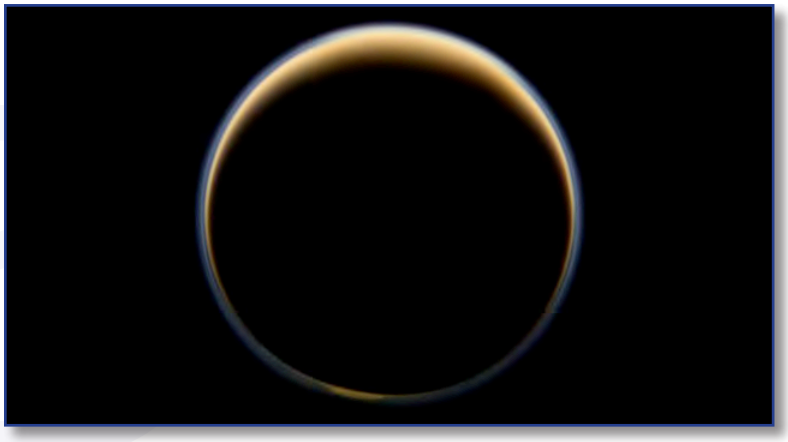
The paper was authored by scientists from a number of other NASA centers and universities, including the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland; University of Colorado, Boulder; University of Texas, Austin; and the NASA Goddard Space Flight Center, Greenbelt, Maryland. The team found the most important questions clustered around composition: What makes up the reddish "freckles" and reddish cracks that stain the icy surface? What kind of chemistry is occurring there? Are there organic molecules, which are among the building blocks of life?

Additional priorities involved improving our images of Europa — getting a look around at features on a human scale to provide context for the compositional measurements. Also among the top priorities were questions related to geological activity and the presence of liquid water: How active is the surface? How much rumbling is there from the periodic gravitational squeezes from its planetary host, the giant planet Jupiter? What do these detections tell us about the characteristics of liquid water below the icy surface?

"Landing on the surface of Europa would be a key step in the astrobiological investigation of that world," said Chris McKay, a senior editor of the journal *Astrobiology*, who is based at NASA Ames Research Center, Moffett Field, California. "This paper outlines the science that could be done on such a lander. The hope would be that surface materials, possibly near the linear crack features, include biomarkers carried up from the ocean."

Cassini Sees Precursors to Aerosol Haze on Titan

Scientists working with data from NASA's Cassini mission have confirmed the presence of a population of complex hydrocarbons in the upper atmosphere of Saturn's largest moon, Titan, that later evolve into the components that give the moon a distinctive orange-brown haze. The presence of these complex, ringed hydrocarbons, known as polycyclic aromatic hydrocarbons (PAHs), explains the origin of the aerosol particles found in the lowest haze layer that blankets Titan's surface. Scientists think these PAH compounds aggregate into larger particles as they drift downward.



NASA's Cassini spacecraft looks toward the nightside of Saturn's largest moon and sees sunlight scattering through the periphery of Titan's atmosphere and forming a ring of color. Credit: NASA/JPL-Caltech/Space Science Institute.

Of all the bodies in the solar system, Saturn's largest moon, Titan, has the atmosphere most resembling that of Earth. Like that of our planet, Titan's atmosphere is largely composed of molecular nitrogen. Unlike Earth's atmosphere, however, Titan's contains only small traces of oxygen and water. Another molecule, methane, plays a similar role to that of water in Earth's atmosphere, and makes up about 2% of Titan's atmosphere. Scientists have speculated

that the atmosphere of this moon may resemble that of our planet in its early days, before primitive living organisms enriched it with oxygen via photosynthesis.

When sunlight or highly energetic particles from Saturn's magnetic bubble hit the layers of Titan's atmosphere above about 1000 kilometers (600 miles), the nitrogen and methane molecules there are broken up. This results in the formation of massive positive ions and electrons, which trigger a chain of chemical reactions, producing a variety of hydrocarbons — a wide range of which have been detected in Titan's atmosphere. These reactions eventually lead to the production of carbon-based aerosols, large aggregates of atoms and molecules that are found in the lower layers of the haze that enshrouds Titan, well below 500 kilometers (300 miles). The process is similar to Earth, where smog starts with sunlight breaking up hydrocarbons that are emitted into the air. The resulting pieces recombine to form more complex molecules.

Aerosols in Titan's lower haze have been studied using data from the descent of the European Space Agency's Huygens probe, which reached the surface in 2005, but their origin remained unclear. New studies analyzing data from Cassini's visual and infrared mapping spectrometer (VIMS) gathered in July and August 2007 might solve the problem. One new study of Titan's upper atmosphere in the *Astrophysical Journal* describes the detection of the PAHs, which are large carbon-based molecules that form from the aggregation of smaller hydrocarbons.

"We can finally confirm that PAHs play a major role in the production of Titan's lower haze, and that the chemical reactions leading to the formation of the haze start high up in the atmosphere," said the paper's lead author, Manuel López-Puertas from the Astrophysics Institute of Andalucia in Granada, Spain. "This finding is surprising: We had long suspected that PAHs and aerosols were linked in Titan's atmosphere, but didn't expect we could prove this with current instruments." The team of scientists had been studying the emission from various molecules in Titan's atmosphere when they stumbled upon a peculiar feature in the data. One of the characteristic lines in the spectrum — from methane emissions — had a slightly anomalous shape, and the scientists suspected it was hiding something.

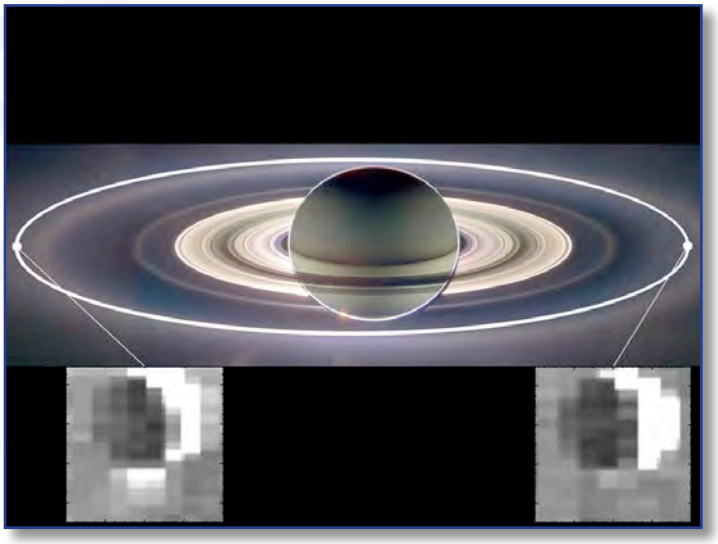
Bianca Maria Dinelli from the Institute of Atmospheric Sciences and Climate (part of the National Research Council) in Bologna, Italy, was the lead author of a related paper in the journal *Geophysical Research Letters*. She and her colleagues conducted a painstaking investigation to identify the chemical species responsible for the anomaly. The additional signal was found only during daytime, so it clearly had something to do with solar irradiation. "The central wavelength of this signal, about 3.28 microns, is typical for aromatic compounds — hydrocarbon molecules in which the carbon atoms are bound in ring-like structures," said Dinelli.

After they ruled out benzene, the scientists tried to reproduce the observed emission with the more complex PAHs. They checked their data against the NASA Ames PAH Infrared Spectral Data Base. And they were successful: The data can be explained as emission by a mixture of many different PAHs, which contain an average of 34 carbon atoms and about 10 rings each.

"PAHs are very efficient in absorbing ultraviolet radiation from the Sun, redistributing the energy within the molecule and finally emitting it at infrared wavelengths," said co-author Alberto Adriani from the Institute for Space Astrophysics and Planetology at Italy's National Institute for Astrophysics (INAF) in Rome. He is part of the Cassini-VIMS co-investigators team and started this investigation. He manages the team that collected and processed VIMS data.

These hydrocarbons also are peculiarly capable of sending out profuse amounts of infrared radiation even in the rarefied environment of Titan's upper atmosphere, where the collisions between molecules are not very frequent. The molecules are themselves an intermediate product, generated when radiation from the Sun ionizes smaller molecules in the upper atmosphere of Titan that then coagulate and sink.

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



This set of images from NASA's Cassini mission shows how the gravitational pull of Saturn affects the amount of spray coming from jets at the active moon Enceladus. Enceladus has the most spray when it is farthest away from Saturn in its orbit (inset image on the left) and the least spray when it is closest to Saturn (inset image on the right). Credit: NASA/JPL-Caltech/University of Arizona/Cornell/SSI.

NASA's Cassini Spacecraft Reveals Forces Controlling Saturn Moon Jets

The intensity of the jets of water ice and organic particles that shoot out from Saturn's moon Enceladus depends on the moon's proximity to the ringed planet, according to data obtained by NASA's Cassini spacecraft. The finding adds to evidence that a liquid water reservoir or ocean lurks under the icy surface of the moon. This is the first clear observation the bright plume emanating from Enceladus' south pole varies predictably. The findings are detailed in a scientific paper in the July edition of *Nature*.

"The jets of Enceladus apparently work like adjustable garden hose nozzles," said Matt Hedman, the paper's lead author and a Cassini team scientist based at Cornell University in Ithaca, New York. "The nozzles are almost closed when Enceladus is closer to Saturn and are most open when the moon is farthest away. We think this has to do with how Saturn squeezes and releases the moon with its gravity."

Cassini, which has been orbiting Saturn since 2004, discovered the jets that form the plume in 2005. The water ice and organic particles spray out from several narrow fissures nicknamed "tiger stripes." "The way the jets react so responsively to changing stresses on Enceladus suggests they have their origins in a large body of liquid water," said Christophe Sotin, a co-author and Cassini team member at NASA's Jet Propulsion Laboratory. "Liquid water was key to the development of life on Earth, so these discoveries whet the appetite to know whether life exists everywhere water is present."

For years scientists hypothesized the intensity of the jets likely varied over time, but no one had been able to show they changed in a recognizable pattern. Hedman and colleagues were able to see the changes by examining infrared data of the plume as a whole, obtained by Cassini's visual and infrared mapping spectrometer (VIMS), and looking at data gathered over a long period of time. The VIMS instrument, which enables the analysis of a wide range of data including the hydrocarbon composition of the surface of another saturnian moon, Titan, and the seismological signs of Saturn's vibrations in its rings, collected more than 200 images of the Enceladus plume from 2005 to 2012. These data show the plume was dimmest when the moon was at the closest point in its orbit to Saturn. The plume gradually brightened until Enceladus was at the most distant point, where it was three to four times brighter than the dimmest detection. This is comparable to moving from a dim hallway into a brightly lit office.

Adding the brightness data to previous models of how Saturn squeezes Enceladus, the scientists deduced the stronger gravitational squeeze near the planet reduces the opening of the tiger stripes and the amount of material spraying out. They think the relaxing of Saturn's gravity farther away from planet allows the tiger stripes to be more open and for the spray to escape in larger quantities.

WISE Finds Mysterious Centaurs May Be Comets

The true identity of centaurs, the small celestial bodies orbiting the Sun between Jupiter and Neptune, is one of the enduring mysteries of astrophysics. Are they asteroids or comets? A new study of observations from NASA's Wide-field Infrared Survey Explorer (WISE) finds most centaurs are comets.

Until now, astronomers were not certain whether centaurs are asteroids flung out from the inner solar system or comets traveling in toward the Sun from afar. Because of their dual nature, they take their name from the creature in Greek mythology whose head and torso are human and legs are those of a horse.

New observations from NASA's NEOWISE project reveal the hidden nature of centaurs, objects in our solar system that have confounded astronomers for resembling both asteroids and comets. The centaurs, which orbit between Jupiter and Neptune, were named after the mythical half-horse, half-human creatures called centaurs due to their dual nature. This artist's concept shows a centaur creature together with asteroids on the left and comets at right. Credit: NASA/JPL-Caltech.

"Just like the mythical creatures, the centaur objects seem to have a double life," said James Bauer of NASA's Jet Propulsion Laboratory. Bauer is lead author of a paper published online July 22 in the *Astrophysical Journal*. "Our data point to a cometary origin for most of the objects, suggesting they are coming from deeper out in the solar system." "Cometary origin" means an object likely is made from the same material as a comet, may have been an active comet in the past, and may be active again in the future.

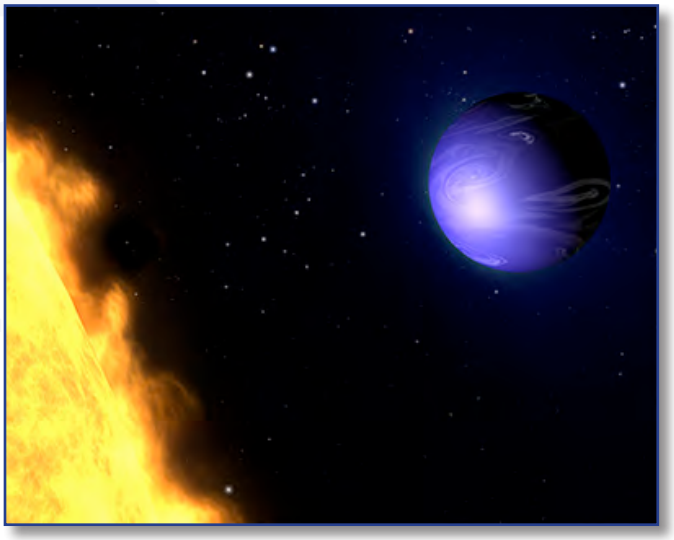
The findings come from the largest infrared survey to date of centaurs and their more distant cousins, called scattered disk objects. NEOWISE, the asteroid-hunting portion of the WISE mission, gathered infrared images of 52 centaurs and scattered disk objects. Fifteen of the 52 are new discoveries. Centaurs and scattered-disk objects orbit in an unstable belt. Ultimately, gravity from the giant planets will fling them either closer to the Sun or farther away from their current locations.

Infrared data from NEOWISE provided information on the objects' albedos, or reflectivity, to help astronomers sort the population. NEOWISE can tell whether a centaur has a matte and dark surface or a shiny one that reflects more light. The puzzle pieces fell into place when astronomers combined the albedo information with what was already known about the colors of the objects. Visible-light observations have shown centaurs generally to be either blue-gray or reddish in hue. A blue-gray object could be an asteroid or comet. NEOWISE showed that most of the blue-gray objects are dark, a telltale sign of comets. A reddish object is more likely to be an asteroid. "Comets have a dark, soot-like coating on their icy surfaces, making them darker than most asteroids," said the study's co-author, Tommy Grav of the Planetary Science Institute in Tucson, Arizona. "Comet surfaces tend to be more like charcoal, while asteroids are usually shinier like the moon."

The results indicate that roughly two-thirds of the centaur population are comets, which come from the frigid outer reaches of our solar system. It is not clear whether the rest are asteroids. The centaur bodies have not lost their mystique entirely, but future research from NEOWISE may reveal their secrets further. For more information, visit *www.nasa.gov/wise* or *wise.ssl.berkeley.edu*.

NASA Hubble Finds a True Blue Planet

Astronomers making visible-light observations with NASA's Hubble Space Telescope have deduced the actual color of a planet orbiting another star 63 light-years away. The planet is HD 189733b, one of the closest exoplanets that can be seen crossing the face of its star.



This illustration shows a hot-Jupiter-class planet orbiting its yellow-orange star, HD 189733. NASA's Hubble Space Telescope measured the actual visible-light color of the planet, which is deep blue. Credit: NASA, ESA, and G. Bacon (STScI).

Hubble's Space Telescope Imaging Spectrograph measured changes in the color of light from the planet before, during, and after a pass behind its star. There was a small drop in light and a slight change in the color of the light. "We saw the light becoming less bright in the blue but not in the green or red. Light was missing in the blue but not in the red when it was hidden," said research team member Frederic Pont of the University of Exeter in South West England. "This means that the object that disappeared was blue."

Earlier observations have reported evidence for scattering of blue light on the planet. The latest Hubble observation confirms the evidence. If seen directly, this planet would look like a deep blue dot, reminiscent of Earth's color as seen from space. That is where the comparison ends. On this turbulent alien world, the daytime temperature is nearly 1093°C (2000°F), and it possibly rains glass — sideways — in howling, 7242-kilometer-per-hour (4500 miles per hour) winds. The cobalt blue color comes not from the reflection of a tropical ocean as it does on Earth, but rather a hazy, blow-torched atmosphere containing high clouds laced with silicate particles. Silicates condensing in the heat could form very small drops of glass that scatter blue light more than red light.

Hubble and other observatories have made intensive studies of HD 189733b and found its atmosphere to be changeable and exotic. HD 189733b is among a bizarre class of planets called hot Jupiters, which orbit precariously close to their parent stars. The observations yield new insights into the chemical composition and cloud structure of the entire class. Clouds often play key roles in planetary atmospheres. Detecting the presence and importance of clouds in hot Jupiters is crucial to astronomers' understanding of the physics and climatology of other planets.

HD 189733b was discovered in 2005. It is only 4.6 million kilometers (2.9 million miles) from its parent star, so close that it is gravitationally locked. One side always faces the star and the other side is always dark. In 2007, NASA's Spitzer Space Telescope measured the infrared light, or heat, from the planet, leading to one of the first temperature maps for an exoplanet. The map shows dayside and nightside temperatures on HD 189733b differ by about 260°C (500°F). This should cause fierce winds to roar from the dayside to the nightside.

For more information, visit *www.hubblesite.org* or *exoplanets.org*.

NASA Ends Attempts to Fully Recover Kepler Spacecraft, Potential New Missions Considered

Following months of analysis and testing, the Kepler Space Telescope team is ending its attempts to restore the spacecraft to full working order, and now is considering what new science research it can carry out in its current condition. Two of Kepler's four gyroscope-like reaction wheels, which are used to precisely point the spacecraft, have failed. The first was lost in July 2012, and the second in May of this year. Engineers' efforts to restore at least one of the wheels have been unsuccessful.

An artist's composite of the Kepler telescope. Two of Kepler's four gyroscope-like reaction wheels, which are used to precisely point the spacecraft, have failed, and NASA is ending attempts to fully recover the spacecraft.

Kepler completed its prime mission in November 2012 and began its four-year extended mission at that time. However, the spacecraft needs three functioning wheels to continue its search for Earth-sized exoplanets, which are planets outside our solar system, orbiting stars like our Sun in what's known as the habitable zone — the range of distances from a star where the surface temperature of a planet might be suitable for liquid water. As scientists analyze previously collected data, the Kepler team also is looking into whether the space telescope can conduct a different type of science program, including an exoplanet search, using the remaining two good reaction wheels and thrusters.

"Kepler has made extraordinary discoveries in finding exoplanets including several super-Earths in the habitable zone," said John Grunsfeld, associate administrator for NASA's Science Mission Directorate in Washington. "Knowing that Kepler has successfully collected all the data from its prime mission, I am confident that more amazing discoveries are on the horizon."

On August 8, engineers conducted a system-level performance test to evaluate Kepler's current capabilities. They determined that wheel 2, which failed last year, can no longer provide the precision pointing necessary for science data collection. The spacecraft was returned to its point rest state, which is a stable configuration where Kepler uses thrusters to control its pointing with minimal fuel use.

"At the beginning of our mission, no one knew if Earth-sized planets were abundant in the galaxy. If they were rare, we might be alone," said William Borucki, Kepler science principal investigator at NASA's Ames Research Center. "Now at the completion of Kepler observations, the data holds the answer to the question that inspired the mission: Are Earths in the habitable zone of stars like our Sun common or rare?"

An engineering study will be conducted on the modifications required to manage science operations with the spacecraft using a combination of its remaining two good reaction wheels and thrusters for spacecraft attitude control. Informed by contributions from the broader science community in response to the call for scientific white papers announced August 2, the Kepler project team will perform a study to identify possible science opportunities for a two-wheel Kepler mission. Depending on the outcome of these studies, which are expected to be completed later this year, NASA will assess the scientific

priority of a two-wheel Kepler mission. Such an assessment may include prioritization relative to other NASA astrophysics missions competing for operational funding at the NASA Senior Review board early next year.

From the data collected in the first half of its mission, Kepler has confirmed 135 exoplanets and identified over 3500 candidates. The team continues to analyze all four years of collected data, expecting hundreds, if not thousands, of new discoveries including the long-awaited Earth-sized planets in the habitable zone of Sun-like stars. Although the spacecraft will no longer operate with its unparalleled precision pointing, scientists expect Kepler's most interesting discoveries are still to come.

For more information about NASA's Kepler spacecraft, visit *www.nasa.gov/kepler*.

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

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

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

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

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Wiki Your Science

Since 2001, when Wikipedia came on the scene, it has grown to be one of the most referenced websites on the Internet. Millions are guided to Wikipedia when searching the web for a variety of information, including information about lunar and planetary science.

The Lunar and Planetary Institute encourages scientists and postdoctoral researchers to share their expertise and enthusiasm for planetary science by becoming writers and contributing editors on Wikipedia. There are many ways to get involved — identifying and correcting errors, omissions, and inadequate citations, as well as creating new, original pages. And because Wikipedia is available in many different languages, there is also a need for translation of existing pages.

It's easy to get started. Go to Wikipedia and create a free account by choosing a username and password. Once you've registered, you can edit existing pages and write new pages in Wikipedia.

Editing

Editing Wikipedia pages is easy and is a great way to get started in Wikipedia. Once you've logged on with your username and password, go to the page you'd like to edit by doing a search, then click on the Edit tab at the top of the page. You'll get a new page with a text box with editable text of the current page. At this point you can use Wiki Markup language to edit the page. Once you've made changes to the page, click on Show preview at the bottom of the text box to see what the changes will look like once they go live. Once the page looks the way you want with your changes, you can click on Save page to make the page go live. At this point, the page is part of Wikipedia and available for others to read and edit. All changes made by all editors of that page can be viewed by clicking on the View history tab at the top of the page.

Writing

See if the page you want to create already exists by doing a search. If the page doesn't already exist, ask yourself the following: Is the subject worthwhile, notable, and verifiable? A subject must meet these standards before a page is created. Log on with your username and password, then click on Create an article now. You'll get a new page with an empty text box in which to start creating your page with Wiki Markup language. Write a short introduction and the main body of the page. Click on Show preview at the bottom of the text box to see what the new page will look like once it goes live. Proofread it carefully for spelling and grammatical errors. Once the page looks the way you want, you can click on Save page to make the page go live. Now others can see this new page and add to it or edit. All changes made by all editors of that page can be viewed by clicking on the View history tab at the top of the page.

Wikipedia is a collaborative effort, and anyone can create new pages or edit the pages that exist. There is, however, a "Wikipedia style" that is expected: Content must be authoritative, neutral, and verifiable. Pages that do not meet the standards will receive warnings by Wikipedia editors and may be taken down.

Because of its collaborative nature, writers and editors in Wikipedia should expect to have their work modified over time. It is important not to take changes to your work personally. This is not an individual effort — it's a group effort.

There is a lot of information available about editing and writing in Wikipedia, including in Wikipedia itself.

Helpful Websites

Wiki markup quick reference
en.wikipedia.org/wiki/Help:Wikitext_quick_reference

Ten Simple Rules for Editing Wikipedia
www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1000941

Helpful Books

How Wikipedia Works and How You Can Be a Part of It
by Phoebe Ayers, Charles Matthews, and Ben Yates (2008, No Starch Press), ISBN 159327176X

Wikipedia: The Missing Manual
by John Broughton (2008, O'Reilly Media), ISBN 0596515162

The Complete Guide to Wikis: How to Set Up, Use, and Benefit from Wikis for Teachers, Business Professionals, Families, and Friends
by T. Brian Chatfield (2009, Atlantic Publishing Company), ISBN 1601383193

Join the Wiki Your Science effort and enhance the lunar and planetary science content on Wikipedia!

"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.

Opportunities to Get Involved!

Host your own events this year! Upcoming planetary opportunities exist for educator and public engagement around the broader topics of NASA lunar exploration, Mars exploration, planetary geology, and habitability!

LADEE Launch

NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) Mission is tentatively set to launch September 6, 2013, at 11:27 p.m. ET from NASA Wallops Flight Facility. This nighttime launch could be observable for half of the continental U.S. population and presents a spectacular opportunity to engage and inspire the next generation of lunar explorers!

LADEE provides a variety of exciting opportunities for students and the public to become directly involved in the mission. These activities range from those appropriate for kindergarten through 12th grade students (K–12), to those appropriate for university and college students, to those appropriate for advanced amateur astronomers. Look for resources and more information at moon.nasa.gov/ladeelaunch.cfm, as well as at moon.nasa.gov/moontoolkit.cfm and moon.nasa.gov/home.cfm.

Looking for more details or updates about the LADEE launch, such as when launch will occur and where? For more specific and up-to-date launch information, please visit *www.nasa.gov/missions/highlights/schedule.htm*.

International Observe the Moon Night (InOMN)

Saturday, October 12

Each year, amateur and professional astronomers, lunar scientists, NASA centers, schools, museums, planetariums, and observatories collectively hold hundreds of public events around the world in celebration of International Observe the Moon Night. At these events, the public can learn about the Moon and NASA's missions of lunar science and exploration, and can even make their own firsthand lunar observations through telescopes. A variety of resources are available at *observethemoonnight.org*.

MAVEN to Mars!

The Mars Atmosphere and Volatile Evolution Mission (MAVEN) is set to launch in November 2013! There are a variety of programs for educators available at *lasp.colorado.edu/home/maven*.

Handbook for Geoscientists Interested in Outreach

Visiting Geoscientists: An Outreach Guide for Geoscience Professionals is a handbook co-produced by the American Geosciences Institute (AGI) and the American Association of Petroleum Geologists' Youth Education Activities Committee. Professional geoscientists who visit schools and lead field trips, especially at the K–12 level, provide unique enrichment opportunities. The handbook offers strategies and resources. Various sections discuss how students learn science best, issues in Earth science education, recommendations for volunteers, sample activities, and more. To download the handbook, visit *www.agiweb.org/education/aapg/index.html*.

Earthzine 2013 Student Essay Contest for Undergraduate and Graduate Students

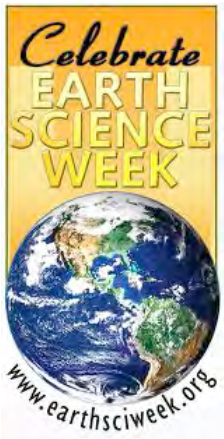
Entries Due September 3

Earthzine invites undergraduate and graduate students from around the world to submit an essay to the 2013 Student Essay Contest. This year's theme is "Science Technology for Observing Earth's Climate." The contest is an opportunity for students to share views on Earth science technology, including hardware for data collection, computer infrastructures for data management, and software and algorithms for data analysis. Accepted essays will be published at *Earthzine.org* and judged by a panel of experts, with $1500 in prizes awarded to the top entry or entries. The process for judging will include two weeks of online discussion with Earthzine readers and judges. For full rules and details, visit *bit.ly/162ym5m*.

Guide to Resources for Teaching about Exoplanets

NASA's Astrophysics Education and Outreach Forum and the Astronomical Society of the Pacific have published an online annotated guide to written, web, and audio-visual resources for teaching about planets orbiting other stars that is now available for high-school and college instructors, their students, informal educators, and astronomy enthusiasts. Materials in the guide to this rapidly changing branch of astronomy include video and audio files of lectures and interviews with leading scientists in the field, phone and tablet apps, a citizen-science website, popular-level books and articles, and much more. To download the guide, visit *www.astrosociety.org/education/astronomy-resource-guides/the-search-for-planets-around-other-stars*.

Geologic Map Contest Invites College Students



As part of Earth Science Week (October 13–19) and Geologic Map Day (October 18), the U.S. Geological Survey invites university-level students to enter its 2013 Best Student Geologic Map Competition. The contest will be judged at the Geological Society of America's Annual Meeting in Denver, October 27–30. While judges select three winners, students will network and share their experiences and techniques.

To be considered, students should contact the official U.S. Geological Survey representative by September 6. To learn more, visit *community.geosociety.org/2013AnnualMeeting/Conference/StudentInfo/MapCompetition*.

NASA Internships and Fellowships

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

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

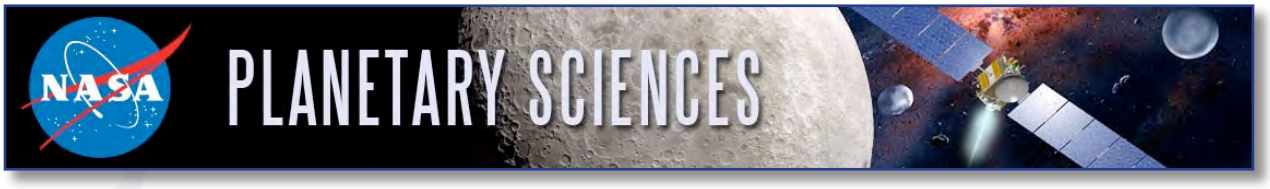
Applications for spring 2014 opportunities are due October 11, 2013. To find available opportunities and to fill out an online OSSI application, visit *intern.nasa.gov/index.html*.

Eugene Shoemaker Impact Cratering Award

Application Deadline September 11, 2013

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, is to be applied for the study of impact craters, either on Earth or on the other solid bodies in the solar system, which areas of study may include but shall not necessarily be limited to impact cratering processes, the bodies (asteroidal or cometary) that make the impacts, or the geological, chemical, or biological results of impact cratering. The application deadline is September 11, 2013. For more information, visit *www.lpi.usra.edu/science/kring/Awards/Shoemaker_Award*.

NASA Planetary Sciences Collection of Videos and Interactives



WGBH Boston has now catalogued and adapted over 30 videos and interactives from NASA, which teachers and students can view and download to explore the exciting discoveries from NASA missions about the planets, moons, and other objects in our solar system. Also available are three professional development videos produced by WNET New York. To access these resources, visit *www.pbslearningmedia.org/collection/npls*.

LPI Educator Resources Online

The Lunar and Planetary Institute's Education Department has produced a variety of Earth and space science resources, including activities, PowerPoints, exhibits, and other resources. The resources are now searchable by age, audience, topic, and resource type. Check it out at *www.lpi.usra.edu/education/resources*.

Michael Wargo

It is with heavy hearts that the planetary science community, and the lunar science community in particular, mourn the passing of a friend and colleague, Michael Wargo. Wargo, Chief Exploration Scientist for NASA's Human Exploration and Operations Mission, died unexpectedly on August 4 at his home in Alexandria, Virginia. He was 61 years old.

Wargo was a leading contributor to NASA's human lunar and planetary exploration program. As a scientific member of many lunar missions, including the Lunar Reconnaissance Orbiter and the LCROSS satellite, he helped map resources for human missions to the Moon and participated in the discovery of ice in the shadows of lunar craters. In a nearly two-decade career at NASA, he received numerous awards, including NASA's Exceptional Service Medal and seven group achievement awards. He was a member of the team planning the next robotic mission to Mars in 2020 and worked gathering crucial scientific information needed to allow humans to be sent safely to the Moon, Mars, and near-Earth asteroids. Much of his work has helped develop a "roadmap" for human and robotic space exploration for the next two decades.

Wargo graduated from the Massachusetts Institute of Technology (MIT) with a degree in Earth and Planetary Science and received a Doctorate in Materials Science in 1982. At MIT, he was recognized with the John Wulff Award for Excellence in Teaching and the Hugh Hampton Young Memorial Fund Prize for exhibiting leadership and creativity while maintaining exceptionally broad and interdisciplinary interests. He began his career at NASA by turning a fledgling microgravity research division into a world-class program. NASA drew on Wargo's ability to explain complex scientific findings in straightforward terms as a spokesman at agency press conferences. NASA is asking the International Astronomical Union to name a crater on the Moon in his honor "so his name will be forever enshrined in the heavens." His colleagues and his friends remember him as inspirational, full of passion and energy, with a booming voice and a great heart. He led by example, working closely with colleagues in the lunar, planetary, and Mars science communities, to build collaborative and highly productive projects for both exploration and science.

— Portions of text courtesy of the LEAG Executive Committee

Paul S. DeCarli

Paul S. DeCarli passed away on August 4, 2013, after a brief battle against an aggressive form of stomach cancer.

DeCarli was born in Stockton, California, in 1930. He began his academic career at Stanford in 1948, and after a stint in the Army from 1952 to 1954 began working at Stanford Research Institute (now SRI International) as a helper and explosives technician, completing his B.Sci. degree in Materials Science in 1957. As low man on the totem pole, DeCarli was assigned to help scientists who visited during the summer to conduct research or simply to learn about shock waves and consult in their specialties. When one of these visitors, John Jamieson, suggested that it might be fun to see whether they could make coesite by shocking quartz, DeCarli designed an experiment

to shock and recover quartz. When DeCarli's post-shock examination showed the recovered sample to be amorphous, he and Jamieson wrote the first paper on shock metamorphism of quartz.

The paper attracted the attention of Gene Shoemaker, whose office at the Menlo Park office of the U.S. Geological Survey was about 100 meters from DeCarli's office. DeCarli gave samples to Shoemaker, who later gave a sample from the very first experiment to Sue Kieffer who went on to study shock metamorphism in Meteor Crater.

During the early 1960s, DeCarli and Thomas Ahrens were funded by NASA to work on shock effects in rocks and minerals. Ahrens took the contract with him when he joined the California Institute of Technology, and DeCarli had to find other sources of support. Because funding was becoming tighter and research contracts were much more narrowly constrained, defense funding appeared the most reliable, so DeCarli moved into the development of shock wave instrumentation. Between 1970 and 1995, most of DeCarli's efforts were devoted to development of shock wave instrumentation and to measurements on various defense-related nuclear and high explosive experiments. Some of this work was performed in conjunction with joint Russian-U.S. programs to monitor the yields of underground nuclear tests.

Upon his retirement in 1995, DeCarli returned his attention to meteoritics and planetary science to help others to better understand shock physics and shock effects in rocks. He remained active in science until the very end, coauthoring a recent Nature Geoscience paper and several other scientific papers currently in preparation. He presented an hour-long lecture at the SETI institute in July of this year entitled "Free Samples from Mars," and he had planned to attend the 2013 meeting of the Meteoritical Society in Edmonton to present results on the importance of shock veins in the survival of shocked meteorites.

DeCarli was a kind and generous colleague. He was also very active in his community, playing the bassoon in his local orchestra, participating in community events, tutoring kids in English, and more. He will be greatly missed by his family, friends, his local community, and by the global scientific community.

— Portions of text courtesy of Thomas Sharp, Arizona State University

George M. Levin

George M. Levin, age 72, died at his home on June 17 after a long battle with lung cancer. Levin began his 35-year NASA career in 1962 at the Goddard Space Flight Center. His professional background included work on the Nimbus weather satellite program and on the planetary exploration program, including the Pioneer Venus Project. From 1972 to 1981 he managed the development of the Hubble Space Telescope's first five scientific instruments as well as the preparations for mission and science operations.

In 1981 Levin moved to NASA Headquarters where he managed the development of 17 successful flight demonstrations launched on both the space shuttle and Delta II rockets, and in 1991 assumed responsibility for managing NASA's Orbital Debris Program. He led the U.S. Delegation to the Interagency Space Debris Coordination Committee (IADC) and was a member of the U.S. Delegation to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space.

Levin was the recipient of numerous awards, including both NASA's Exceptional Service Medal and the Silver Snoopy, awarded to no more than 1% of eligible NASA employees. In 1987 Levin was selected by the White House to be a Presidential Exchange Executive, and in 1999 was elected to membership in the International Academy of Astronautics.

In 1997, after retiring from NASA, Levin joined the National Academies as Director of the Aeronautics and Space Engineering Board. He retired from the National Academies in 2007.

Jeffrey K. Wagner

Dr. Jeffrey K. Wagner, 61, Professor of Astronomy and Geology at Bowling Green State University Firelands College, passed away on July 8 after a short battle with brain cancer. Wagner's name is familiar to everyone in the field of spectroscopy of planetary surfaces. His seminal work on the ultraviolet reflectances of planetary materials, which formed his Ph.D. dissertation, opened a new field in planetary spectroscopy, and the papers resulting from his thesis are still cited more than 30 years later.

Wagner was born on March 11, 1952, in Bellwood, Pennsylvania. He received his B.S. in Astronomy from Penn State University in 1974, and his Ph.D. in Geology and Planetary Sciences from the University of Pittsburgh in 1980. He spent one year at the Talcott Mountain Science Center in Avon, Connecticut, as an Earth Sciences Instructor, and retired in 2011 from Firelands College where he enjoyed 30 years as a Professor of Astronomy and Geology. His 1991 book *Introduction to the Solar System* was often used in the classroom. He served as chair of the Department of Natural and Social Sciences at BGSU Firelands for nine years, helping to grow and advance that department. In 2007, his work in the classroom was recognized with the Distinguished Teaching Award.

Hasso Niemann

Dr. Hasso Niemann died peacefully in his sleep on July 11 after a brief battle with cancer. Niemann was a founding father of atmospheric experiments and mass spectrometry at the NASA Goddard Space Flight Center, studies that ultimately led to the successful SAM experiment that is currently operating on the Curiosity Rover.

Niemann leaves a huge legacy at Goddard and in the planetary and atmospheric sciences community with a career devoted to the development of mass spectrometer technology and using these capabilities to measure the composition of planetary atmospheres. His career began in graduate school with cumbersome rocket flight experiments, and spanned the epoch that saw spaceflight mass spectrometry evolve from crude, heavy laboratory tools to its current highly sophisticated state where mass spectrometers are now viewed as a primary instruments on planetary missions. Early in his career at Goddard, as head of the Atmospheric Experiments Branch, he pioneered *in situ* exploration of the upper atmosphere of the Earth with instruments on several spacecraft. He later focused on planetary atmospheres with the first *in situ* measurements of the upper atmosphere of Venus on the Pioneer Venus Mission and subsequently the deep atmosphere of Jupiter via the prime instrument on the Galileo Probe that allowed fundamental questions regarding the formation mechanisms of giant planets to be addressed. He also contributed greatly to the Cassini mission as Principal Investigator on the Cassini Huygens Gas Chromatograph Mass Spectrometer and the Facility Instrument Provider of the Cassini Ion and Neutral Mass Spectrometer. His legacy continued at Goddard even after his retirement with provision of mass spectrometers by members of his group to missions such as the Mars Science Laboratory and the MAVEN Mars Orbiter.

Niemann cultivated broad and long-lasting collaborations with world-class planetary atmospheric scientists, and published many groundbreaking papers describing the results of these experiments. Among his notable awards were NASA's Distinguished Service Medal for his career contributions in mass spectrometry, the Lindsay award in 1997, and the Al Seiff Memorial Award presented to him after his retirement in 2007. His legacy will live on not only with his many planetary science colleagues, but also with the technical teams that worked with him on all aspects of instrument development. In the words of his colleague Jonathan Lunine, "He touched so many people scientifically and personally. Hasso's kindness in inviting young people like me to be part of his Huygens GCMS proposal, his exemplary leadership and extraordinary work ethic in making the instrument happen, and his graceful and gracious diplomacy in dealing with the myriad people involved in the project (and difficult ones like me) were all lessons in being a good human being that I will never forget."

Mineral Named for Livermore Cosmochemist

A recently discovered mineral appears to be clear but may have a tinge of light blue. No matter its color, you won't be able to make earrings from it. For one thing, you can't see the material with the naked eye. Hutcheonite, recently named after Lawrence Livermore National Laboratory (LLNL) meteorite researcher Ian Hutcheon, can be seen only with high-powered scanning electron microscopes.

Cosmochemist Ian Hutcheon holds a piece of the meteorite Allende, which contains some of the oldest objects in the solar system. A new mineral, hutcheonite, is named in honor of Hutcheon. Credit: Julie Korhummel/LLNL.

Known also by its chemical makeup, $Ca_3Ti_2SiAl_2O1_2$, hutcheonite was discovered in a refractory inclusion in the Allende meteorite by Sasha Krot (University of Hawaii) and Chi Ma (Caltech) and named in honor of Hutcheon, who has made numerous contributions to the study of meteorites and what they can tell us about the evolution of the early solar system. The hutcheonite mineral structure and name have been officially approved by the International Mineralogical Association. The discovery was formally announced at the annual meeting of the Meteoritical Society held recently in Edmonton, Canada.

Refractory inclusions within meteorites are the oldest objects in the solar system. Hutcheon has been studying these, specifically in the meteorite Allende, since his days as a postdoc at the University of Chicago in 1975. Allende is the largest carbonaceous chondrite meteorite ever found on Earth. It fell to the ground in 1969 over the Mexican state of Chihuahua and is notable for possessing abundant inclusions.

"I'm not in the business of discovering minerals," Hutcheon said. "But I am interested in dating when these minerals formed and what happened to them several million years after they formed."

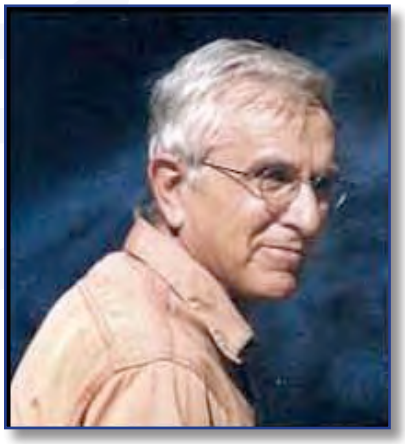
Hutcheon also is interested in finding out when water formed on the asteroid on which Allende and other carbonaceous chondrite meteorites were put together. By looking at the concentrations of elements and isotopes in minerals found in the Allende inclusions, Hutcheon and his team can trace how water got there and ultimately how water developed in the early solar system.

In his nearly 20 years at LLNL, Hutcheon has been a key developer of nuclear forensics as both a field of scientific investigation and a scientific discipline with significant applications to national security. He also has conducted groundbreaking work in the formation mechanisms of planets and meteorites, and subtle, diffusion transport processes in terrestrial and planetary melts, glasses, and minerals, and conducted the first NanoSIMS-enabled studies of biological materials (NanoSIMS is a high resolution imaging mass spectrometer used to probe extremely small materials). Hutcheon, with colleagues, also wrote the definitive nuclear forensics book, *Nuclear Forensic Analysis*. He has been named a Distinguished Member of Technical Staff at LLNL, an honor that is only given to roughly 3–5% of the eligible pool of scientists and engineers.

Hutcheon enrolled in graduate school two months after Neil Armstrong walked on the Moon and was intrigued by studying radiation damage in the Moon samples brought to Earth. However, by the time he became a postdoc, he realized the Moon was relatively young in terms of other objects in the solar system. Meteorites were where it was at.

If it were up to Hutcheon, he would stick strictly to meteorite research. “I would do it full time. It’s great fun. Meteorites are tens of millions of years older than the Moon.”

Hutcheonite is less than one-tenth the width of a human hair and on looks alone may appear to be similar to 11 of the other newly discovered minerals found in Allende. But if you look hard enough, you may just find hutcheonite lurking in a corner of Allende where you never expected to look.



Hartmann Receives 2013 Shoemaker Distinguished Lunar Scientist Award

The new Solar System Exploration Research Virtual Institute (SSERVI) — formerly the NASA Lunar Science Institute — presented William K. (“Bill”) Hartmann with the annual Shoemaker Distinguished Lunar Scientist Award at the 2013 virtual Lunar Science Forum, held July 16–18, 2013, from NASA Ames Research Center.

The Shoemaker Distinguished Lunar Scientist Award is an annual award given to a scientist who has significantly contributed to the field of lunar science throughout the course of their scientific career. The first Distinguished Lunar Scientist Award was given posthumously to Dr. Gene Shoemaker and presented to his wife Carolyn for his many contributions to the lunar geological sciences. The award was subsequently named after Shoemaker and includes a medal with the Shakespearian quote “And he will make the face of heaven so fine, that all the world will be in love with night.” Last year’s Shoemaker award was presented to Stuart Ross Taylor.

“In view of his many fundamental and far-reaching breakthroughs in lunar science such as his discovery of multi-ring impact basins — including Orientale basin — Dr. Hartmann is exceptionally deserving of this medal,” said Yvonne Pendleton, director of the Institute. “We are proud to present him with this honor.”

Hartmann is an internationally known scientist, painter, and writer, and winner of the first Carl Sagan Medal from the American Astronomical Society. A former graduate student of Gerard Kuiper, he holds a Ph.D. in Astronomy and M.S. in Geology, both from the University of Arizona, and a B.S. in Physics from Pennsylvania State University. Hartmann discovered multi-ring impact basins with concentric and radial structure on the Moon, including the Orientale basin on the east limb of the Moon. In 1965 he used crater counts on the Moon and Earth to successfully predict the age of lunar lava plains at 3.6×10^9 years; the date was confirmed five years later with Apollo samples from the Moon. He was lead author, with D. R. Davis, of what has become the most widely accepted theory of the origin of the Moon, by impact of a giant planetesimal at the end of the planet-forming era.

Hartmann has researched Mars extensively as well. He served as a Co-Investigator on the Mariner 9 mission, which first mapped Mars in detail. With Bruce Murray, Carl Sagan, and others on the imaging team, he discovered Mars’ dry river channels, volcanos, and other features. He currently serves on the Mars Global Surveyor imaging team.

Hartmann worked with Dale Cruikshank, David Tholen, and others to recognize that comets have similar black surface materials (4% reflectivity) to those on outer solar system asteroids. This research also yielded proof that Trojan asteroid 624 Hektor was one of the largest highly elongated bodies in the solar system, and the discovery that “asteroid” 2060 Chiron had erupted and turned into a comet. This work recognized that comets and asteroids could no longer be considered as independently as had been previously thought. Asteroid 3341 is named after him.

Hartmann's astronomical paintings have been published in magazines ranging from *Natural History, Smithsonian,* and *Astronomy* in the U.S. to the *London Economist* and other magazines in Japan, Russia, France, Germany, England, and Italy. They have also been shown in exhibitions all over the world, and can be found in collections in the U.S., Paris, and Moscow. Hartmann was commissioned twice to create paintings for the NASA Fine Arts Program (Galileo space probe launch and Mars Observer Mission), and had two paintings flown on the Russian Space Station, Mir, in 1992.

A prolific writer, he has authored three widely-used textbooks on astronomy, and also co-authored and co-illustrated five pictoral books of space art. He has written two novels and published two books sharing his love of western deserts. His immensely successful *A Traveler's Guide to Mars* sold out its first 30,000 copies and went into a second printing within two months. In 1992–1995 he headed an effort for the Planetary Society and National Science Teachers Association to incorporate planetary science materials into the grade 6–12 curriculum. His book of lessons, *Craters!*, was published in 1995 by the National Science Teachers Association.

Dolores Hill (front row, second from the left) addresses the audience regarding the reliability of data of Citizen Science programs at the White House during the Champions of Change Ceremony. Hill was among 12 individuals honored for their contributions to making science and technology accessible through Citizen Science.

Hill Honored at The White House

Dolores Hill, co-lead of the OSIRIS-REx Target Asteroids! program with Carl Hergenrother, was recognized as one of 12 White House Champions of Change for citizen science on June 25, 2013. The White House Champions of Change program recognizes efforts that are changing their communities. This citizen science event honors people and organizations that have demonstrated exemplary leadership in engaging the broader, non-expert community in science, technology, engineering, or mathematics (STEM) research.

Hill was honored at a ceremony at the White House attended by representatives of the Administration and honorees' families, friends, and colleagues. "It is such an honor to be selected and go to the White House for the ceremony. I am especially thrilled that Target Asteroids! combines my lifelong interests in amateur astronomy and meteorites, and brings me in touch with longtime amateur astronomer friends and former colleagues."

As part of NASA's OSIRIS-REx asteroid sample return mission, the Target Asteroids! program involves amateur astronomers in observations of near-Earth asteroids to provide scientists with important information about these objects. These data are intended to aid NASA's OSIRIS-REx mission, led by Dante Lauretta of the University of Arizona, which will visit a near-Earth asteroid in 2018–2021, and return a sample to Earth in 2023. In addition, the Target Asteroids! program will provide data important to future missions to asteroids, and lead to greater understanding of potentially hazardous asteroids. This program expands the role of amateurs in cutting-edge science by building upon the work of a core group of dedicated amateurs who have been tracking asteroids for over a decade, and extending the partnerships between professional and amateur astronomers to produce important results.

Target Asteroids! is part of the Communication and Public Engagement efforts of the OSIRIS-REx mission. Hill suggested the concept and developed it with the mission's educational team during the Concept Study for the mission in 2011. In the program's first year, 138 amateurs registered from 25 states and 26 countries and provided 87 sets of data on 17 near-Earth asteroids. Target Asteroids! also serves as a template for future OSIRIS-REx citizen science programs by demonstrating how to foster collaboration between scientists and the public. Carl Hergenrother, the OSIRIS-REx Astronomy Lead, recognizes the importance of Target Asteroids! participants, "Observations from around the world fill gaps in our knowledge and are an important contributor in revealing these objects as worlds."

In addition to her work on Target Asteroids!, Hill has worked as a meteoriticist at the Lunar and Planetary Laboratory (LPL) of the University of Arizona for 32 years. "Since joining LPL I've followed my passion for studying meteorites to learn about the solar system. I am especially excited to learn more about the 'parent' near-Earth asteroids that produce the meteorites in our collections. OSIRIS-REx is a perfect combination of my interests."

OSIRIS-REx is a NASA New Frontiers mission scheduled to launch in 2016, rendezvous with asteroid (101955) Bennu in 2018, and return a sample to Earth in 2023. For more information about the mission and Target Asteroids!, visit the mission's website, *osiris-rex.lpl.arizona.edu*.

Credit: Baltimore Sun.

NASA Welcomes New Chief Scientist

NASA Administrator Charles Bolden has named planetary geologist Ellen Stofan the agency's chief scientist, effective August 25. Stofan will be Bolden's principal advisor on the agency's science programs and science-related strategic planning and investments.

Prior to her appointment, Stofan was vice president of Proxemy Research in Laytonsville, Maryland, and honorary professor in the Department of Earth Sciences at University College London in England. The appointment marks Stofan's return to NASA. From 1991 through 2000, she held a number of senior scientist positions at NASA's Jet Propulsion Laboratory in Pasadena, California, including chief scientist for NASA's New Millennium Program, deputy project scientist for the Magellan mission to Venus, and experiment scientist for SIR-C, an instrument that provided radar images of Earth on two shuttle flights in 1994.

"Ellen brings an extraordinary range of scientific research knowledge and planetary exploration experience to the chief scientist position," Bolden said. "Her breadth of experience and familiarity with the agency will allow her to hit the ground running. We're fortunate to have her on our team."

Stofan conducts research on the geology of Venus, Mars, Saturn's moon Titan, and Earth. Stofan is an associate member of the Cassini mission to Saturn radar team and a co-investigator on the Mars Express mission's MARSIS sounder. She also was principal investigator on the Titan Mare Explorer, a proposed mission to send a floating lander to a sea on Titan.

Stofan holds master and doctorate degrees in geological sciences from Brown University in Providence, Rhode Island, and a bachelor's degree from the College of William and Mary in Williamsburg, Virginia.

She has received many awards and honors, including the Presidential Early Career Award for Scientists and Engineers. Stofan has authored and published numerous professional papers, books, and book chapters, and has chaired committees including the National Research Council Inner Planets Panel for the recent Planetary Science Decadal Survey and the Venus Exploration Analysis Group.

Lori Garver Announces Departure from NASA Headquarters

Lori Garver, Deputy Administrator at NASA Headquarters, has announced that she will leave the agency effective September 6. Nominated by President Barack Obama and confirmed by the U.S. Senate, Garver began her duties as deputy administrator July 17, 2009.

Credit: NASA/Bill Ingalls.

As deputy administrator, Garver has been NASA's second in command. She works closely with the administrator to provide overall leadership, planning, and policy direction for the agency. Together with the NASA administrator, Garver represents NASA to the Executive Office of the President, Congress, heads of government agencies, international organizations, and external organizations and communities. She also oversees the work of NASA's functional offices.

Garver's confirmation as deputy administrator marked the second time she has worked for NASA. Her first period of service to the agency was from 1996 to 2001. She first served as a special assistant to the NASA administrator and senior policy analyst for the Office of Policy and Plans, before becoming the associate administrator for the Office of Policy and Plans. Reporting to the NASA administrator, she oversaw the analysis, development and integration of policies and long-range plans, the NASA Strategic Management System, and the NASA Advisory Council.

NASA Administrator Charles Bolden issued the following statement about Garver's departure:

"I have had the pleasure and honor of working side by side with Lori for the past four years, as we sought to position the agency for 21st century spaceflight, scientific discovery, and deep space exploration. She has been an indispensable partner in our efforts to keep NASA on a trajectory of progress and innovation. In a time of great change and challenge, she has been a remarkable leader who has consistently shown great vision and commitment to NASA and the aerospace industry.

Lori has led the way on so many of the Obama Administration's space priorities, including our commercial crew and cargo program, the reestablishment of a space technology mission directorate, our use of challenges and prizes, and our unwavering commitment to diversity and inclusion. As one of only a few top women leaders in the aerospace industry, she has been an extraordinary role model for young girls, inspiring them to study science, technology, engineering, and mathematics, and pursue their dreams in space and here on Earth. Lori will always be a great friend to me and to our agency."

AAS Division for Planetary Sciences Announces 2013 Prize Winners

The Division for Planetary Sciences (DPS) of the American Astronomical Society (AAS) is pleased to announce its 2013 prize winners. The prizes will be presented at the 45th annual DPS meeting in Denver, Colorado, in October.

Gerard P. Kuiper Prize for outstanding contributions to the field of planetary science: Dr. Joseph Veverka has made outstanding contributions to the field of planetary science during a career that now spans five decades. He has to his credit a lifetime of outstanding contributions that, in sum, represent a monumental increase in our understanding of planets and, in particular, small bodies — the moons, asteroids, and cometary nuclei in our planetary system. As a planetary scientist, he has defined the field of quantitative study of small bodies in the solar system for a generation (a generation populated by his students and many associates). Veverka is Professor Emeritus at Cornell University and the former James A. Weeks Professor of Physical Sciences and Professor of Astronomy. He was the Deputy Team leader of the Galileo Imaging Science Team and the Principal Science Investigator in the NEAR mission exploration of the asteroids Mathilde and Eros. He was also a member of the Voyager and Cassini imaging teams and led the exploration of comet nuclei on the Deep Impact and Stardust-NExT missions to Comet 9P/Tempel 1 and the EPOXI mission to Comet 103P/Hartley 2.

Harold C. Urey Prize for outstanding achievement in planetary research by a young scientist: Dr. Anders Johansen's pioneering work on planetesimal accretion and more recently on giant planet core formation has provoked paradigm shifts in a field that for years had been plagued by long-standing problems. By filling not one but two major gaps in one of the most difficult areas of solar system studies, Johansen's findings represent one of the most significant contributions to the field. Johansen, currently Associate Senior Lecturer at the University of Lund in Sweden, obtained his bachelor's and master's degrees from Copenhagen University. He finished his Ph.D. in 2007 at the Max Planck Institute for Astronomy in Heidelberg and worked as a postdoctoral fellow at Leiden Observatory. Johansen obtained his docent degree from Lund University in 2013.

Harold Masursky Award for outstanding service to planetary science and exploration: Dr. Ronald Greeley was involved in nearly every major space probe mission flown in the solar system since the Apollo missions to the Moon, including the Galileo mission to Jupiter, Magellan mission to Venus, Voyager 2 mission to Uranus and Neptune, and shuttle imaging radar studies of Earth. Passionate about Mars exploration, he was involved with several missions to the Red Planet, including Mariners 6, 7, and 9; Viking; Mars Pathfinder; Mars Global Surveyor; and the Mars Exploration Rovers. He was a co-investigator for the High Resolution Stereo Camera on the European Mars Express mission. Greeley was a Regents Professor of Planetary Geology at Arizona State University until his death on October 27, 2011. He received his Ph.D. in geology in 1966 from the University of Missouri at Rolla. Through service in the U.S. Army, he was assigned to NASA's Ames Research Center in 1967, where he trained astronauts and helped prepare for the Apollo missions to the Moon. After his military service ended, he remained at NASA Ames to conduct research in planetary geology. Greeley joined the faculty at Arizona State University in 1977 with a joint professorship in the Department of Geology and the Center for Meteorite Studies.

Carl Sagan Medal for outstanding communication by an active planetary scientist to the general public: Dr. Donald Yeomans has been, for more than two decades, the "go to" person for reporters seeking a planetary scientist to illuminate the scientific middle ground between the sublime and the ridiculous. The inevitability of collisions between asteroids and the Earth is a topic that naturally engages public interest. Yeomans capitalized on his roles as manager of the NASA Near Earth Object Program Office at JPL and a co-investigator on the Deep Impact mission to build a lengthy resume of

media appearances, outreach events, and popular press contributions. His calm demeanor and scientific rigor have helped to dampen doomsday hysteria and sound the all-clear on more serious potential risks (e.g., Apophis) when improved observations warrant. Yeomans received his Ph.D. from the University of Maryland and worked as a contractor for the Goddard Space Flight Center before moving to the Jet Propulsion Laboratory in 1976. He is a prolific author with more than 160 professional publications and numerous writings in the popular press. He has authored five books, most recently his 2012 work, *NEOS: Finding Them Before They Find Us*. In recognition of the importance of Yeomans's role, he was recently named one of the 100 Most Influential People in the world by *TIME* magazine.

Jonathan Eberhart Planetary Sciences Journalism Award to recognize and stimulate distinguished popular writing on planetary sciences: Richard A. Kerr is a journalist who has spent his entire professional career covering Earth and planetary science news for Science magazine. Kerr studied oceanography at the College of Wooster. Following two deployments in the navy during the Vietnam War, he pursued a Ph.D. in oceanography at the University of Rhode Island. He has received numerous awards for his outstanding contributions to science journalism. A testament to his unflagging effort to promote planetary sciences though Science is the 2012 article entitled "Peering Inside the Moon to Read Its Earliest History." The article focuses on the violent impact history of our Moon as observed by the GRAIL mission. For this engaging and stimulating article, the Division for Planetary Sciences is pleased to present the 2013 Jonathan Eberhart Planetary Sciences Journalism Award to Kerr.

NASA Selects Innovative Technology Proposals for Suborbital Flights

NASA has selected for possible flight demonstration 10 proposals from six U.S. states for reusable, suborbital technology payloads, and vehicle capability enhancements with the potential to revolutionize future space missions. After the concepts are developed, NASA may choose to fly the technologies to the edge of space and back on U.S. commercial suborbital vehicles and platforms. These types of flights provide opportunities for testing in microgravity before the vehicles are sent into the harsh environment of space.

"As we prepare to venture forth in future science and exploration missions, one of our greatest challenges in advancing cutting-edge technologies is bridging the gap between testing a component or prototype in a laboratory or ground facility and demonstrating that technology or capability in a mission-relevant operational environment," said Michael Gazarik, NASA's associate administrator for space technology in Washington. "Microgravity suborbital flights provide relevant environment testing at a small fraction of the costs required for orbital flights, while advancing technologies that benefit American businesses and our economy."

The proposals selected for technology payloads include "Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications," Johns Hopkins University, Baltimore; "Spacecraft Disturbance Isolation and Rejection Platform," NASA's Jet Propulsion Laboratory, Pasadena, California; "Focal Plane Actuation to Achieve Ultra-High Resolution on Suborbital Balloon Payloads," Arizona State University, Tempe; "Rocket Flight of a Delta-Doped CCD Focal Plane Array to Prove Flight Rating," Arizona State University; and "EDL Technology Development for the Maraia Earth Return Capsule," NASA's Johnson Space Center, Houston.

The solicitation also included a topic on small spacecraft propulsion technologies sponsored by the agency's Small Spacecraft Technology Program, which develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations. Five awards were made under this category: "Operational Demonstration of the MPS-120 CubeSat High-Impulse Adaptable Modular Propulsion System," Aerojet General Corp., Redmond, Washington; "Iodine RF Ion Thruster Development," Busek Company Inc., Natick, Massachusetts; "1U CubeSat Green Propulsion System with Post-Launch Pressurization," Busek Company Inc.; "Advanced Hybrid Rocket Motor Propulsion Unit for CubeSats (PUC)," Aerospace Corp., El Segundo, California; and "Inductively Coupled Electromagnetic (ICE) Thruster System Development for Small Spacecraft Propulsion," by MSNW LLC, Redmond, Washington.

Proposals in response to this solicitation came from NASA centers, federally funded research and development centers, universities, and industry. Following final contract negotiations, awards are expected to be worth as much as $250,000 for one year, with NASA's investment totaling approximately $2 million for all awards. NASA's Flight Opportunities Program sponsored the solicitation through the agency's Game Changing Development Program. Flight demonstrations will be funded separately and based on the availability of appropriated funds.

The Game Changing Development, Flight Opportunities and Small Spacecraft Technology Programs are all part of NASA's Space Technology Mission Directorate, which is innovating, developing, testing and flying hardware for use in the agency's future missions. For more information about NASA's Space Technology Mission Directorate, visit *www.nasa.gov/spacetech*.

NASA and Italian Space Agency Sign Agreement on Exploration of Mercury

At a meeting in Rome on June 20, NASA Administrator Charles Bolden and Italian Space Agency (ASI) President Enrico Saggese signed a Memorandum of Understanding for cooperation on the European Space Agency (ESA)-led BepiColombo mission to Mercury, strengthening mutually beneficial cooperation between NASA and ASI in planetary exploration.

Bolden and Saggese also discussed NASA's plans for a new asteroid initiative, previously announced in President Obama's fiscal year 2014 budget proposal. Saggese expressed the strong interest of Italy for the initiative and welcomed the opportunity to discuss potential ASI participation in a long-term exploration strategy.

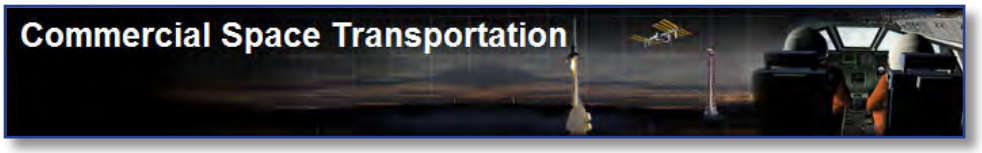
NASA and Korean Space Agency Discuss Space Cooperation

NASA Administrator Charles Bolden and the president of the Korea Aerospace Research Institute (KARI), Seung Jo Kim, met in Washington on July 29 to discuss collaboration in aeronautics research and space exploration, including KARI's robotic lunar mission and NASA's asteroid initiative. This was the first meeting between Bolden and Kim.

"Our two agencies share a mutual interest in aeronautics research, and have identified opportunities for collaboration," said Bolden. "We also have partnered for several years in the International Space Exploration Coordination Group and are looking forward to continued discussions on potential cooperation in space exploration." Bolden and Kim also discussed NASA's plans for a new asteroid initiative, previously announced in President Obama's fiscal year 2014 budget proposal. Kim welcomed the chance to discuss opportunities for collaboration.

NASA's asteroid initiative involves robotically capturing a small near-Earth asteroid and redirecting it safely to a stable lunar orbit where astronauts can explore it. Capturing and redirecting an asteroid integrates the best of NASA's science, technology and human exploration capabilities and draws on the innovation of America's brightest scientists and engineers. The knowledge gained from the initiative will help us protect our planet, advance exploration capabilities and technologies for human spaceflight, and help us better utilize our space resources.

NASA Announces Effort to Form New Collaborative Partnerships with Private Space Industry



NASA officials released a synopsis on July 17 requesting information from U.S. private enterprises interested in pursuing unfunded partnerships. The aim is to advance the development of commercial space products and services.

The Collaborations for Commercial Space Capabilities synopsis describes a potential opportunity for existing and new companies and nonprofit organizations to access NASA's spaceflight expertise for mutually beneficial space exploration goals. These new partnerships are intended to help companies accelerate their development efforts while enabling the nation to reap economic benefits from previous NASA work. NASA benefits by advancing the commercial space industry. This is a primary goal of the National Space Policy and NASA Strategic Plan, which enhance the U.S. aerospace industrial base and could lead to the availability of cost-effective commercial products and services to support human space exploration.

"As we have seen with NASA's previous agreements with the private sector, U.S. companies could significantly benefit from the agency's extensive experience and knowledge in spaceflight development and operations," said Phil McAlister, NASA's director for Commercial Spaceflight Development. "For new entrepreneurial efforts in space, NASA's archive of lessons learned, technical expertise, and spaceflight data is an invaluable national resource and engine for new economic growth."

While NASA works with U.S. industry partners to develop and advance new commercial space capabilities, the agency also is developing the Orion spacecraft and the Space Launch System (SLS), a crew capsule and heavy-lift rocket to provide an entirely new capability for human exploration. Designed to be flexible for launching spacecraft for crew and cargo missions, SLS and Orion will expand human presence beyond low-Earth orbit and enable new missions of exploration in the solar system, including to an asteroid and Mars.

The Collaborations for Commercial Space Capabilities synopsis is available at *go.nasa.gov/16Jex3j*. For more information about NASA initiatives and commercial space, visit *www.nasa.gov/commercial*.

NASA Announces 2013 Aeronautics Scholarship Recipients

NASA has selected 25 students from across the nation to receive the agency's Aeronautics Scholarship for the 2013–2014 school year. This scholarship program, which is in its sixth year, is designed to assist undergraduate and graduate students enrolled in fields of study related to aeronautics and aviation. Recipients were selected from hundreds of applications to the program.

"Future innovation in aeronautics is dependent on today's engineering students," said Jaiwon Shin, associate administrator for NASA's Aeronautics Research Mission Directorate in Washington. "Developing new advances in air transportation is critical if the United States is to remain a world leader in aviation. As engineers, these scholars will be challenged to solve the problems facing the aviation industry as the demand for air travel increases."

The students will have the opportunity to intern with NASA researchers and work on developing technologies for managing air traffic more efficiently. In addition, they will work on technologies that reduce aircraft noise, fuel consumption, and emissions, and improve air safety. This year's recipients are enrolled at universities in California, Georgia, Idaho, Indiana, Iowa, Maryland, Massachusetts, Michigan, Missouri, New Jersey, New York, North Carolina, Ohio, Texas and Wisconsin.

Undergraduate scholarship winners will receive $15,000 per year to cover tuition costs for two years and a $10,000 stipend during a summer internship with NASA. Graduate scholarship winners will receive approximately $45,000 per year for as many as three years and $10,000 stipends for as many as two summer internships. To maintain their scholarship awards, all recipients must continue to meet the academic standards of the universities they attend.

For a list of the 2013 scholarship recipients' names and their schools, visit *www.aeronautics.nasa.gov/2013_scholarship_recipients.htm*. For more information about aeronautics research at NASA, visit *www.aeronautics.nasa.gov*.

Education Research Program Award Recipients Announced

NASA has awarded $10.5 million to colleges and universities to conduct research and technology development in areas important to the agency's mission, develop faculty, and support higher education students. Fourteen proposals were selected for funding in Alaska, Alabama, Hawaii, Kentucky, Louisiana, Missouri, Montana, Nebraska, Nevada, Oklahoma, Rhode Island, Utah, West Virginia, and Wyoming. Winning proposals were selected through a merit-based, peer-reviewed competition.

One proposal was selected from each of the following universities and organizations: Brown University, Providence, Rhode Island; Louisiana Board of Regents, Baton Rouge; Montana State University, Bozeman; University of Alabama, Huntsville; University of Alaska, Fairbanks; University of Hawaii, Honolulu; University of Kentucky, Lexington; University of Missouri, Rolla; University of Nebraska, Omaha; University of Nevada, Reno; University of Oklahoma, Norman; University of Utah, Salt Lake City; University of Wyoming, Laramie; and West Virginia University, Morgantown.

The selections are part of NASA's Experimental Program to Stimulate Competitive Research (EPSCoR). The program helps develop partnerships among NASA research missions and programs, academic institutions and industry. It also helps the awardees establish long-term academic research enterprises that will be self-sustaining and competitive, and contribute to the jurisdictions' economic viability and development.

For additional information about the 2013 EPSCoR selectees, visit *go.nasa.gov/16o5ULe*.

NASA Announces Global Best in Class Winners for the International Space Apps Challenge

A panel of international judges from NASA, the European Space Agency (ESA), and other partner organizations has selected five "best in class" solutions as winners of the 2013 International Space Apps Challenge. The challenge, in which participants developed software, hardware, data visualization, and mobile or Web applications that contribute to space exploration missions and help improve life on Earth, took place at 83 locations around the world earlier this year.

The winners are:

— Best Use of Data: Sol (Kansas City)
Sol is the world's first interplanetary weather application. Users can select a planet and view the weather there, as they might view the weather on Earth by typing a postal code. The Sol team also built the Mars Atmospheric Aggregation System (MAAS) API, used to fuel several of the Mars weather applications produced during the challenge.

— Best Use of Hardware: ISS Base Station (Philadelphia)
ISS Base Station is a hardware-software co-design project both expanding the Spot The Station web app and allowing for a physical manifestation of its data. The software side of the project consists of a simple web app that tracks the position of the International Space Station (ISS) in real time over a map of the

world and connects to an augmented-reality iOS app that allows the user to find the station in the sky. The hardware side consists of a physical device that receives data from the app and points at the current location of the space station, lighting up when the station is within the user's area.

— Best Mission Concept: Popeye on Mars (Athens, Greece)
Popeye on Mars is a deployable, reusable spinach greenhouse for Mars. Internally, a fully equipped aeroponic, or air garden, system operates for 45 days, having all the needed resources, sensors, and electronic systems to stabilize the internal environment and help the spinach grow. There are also systems for harvesting both the plants and the oxygen produced during the growth process. Photovoltaic panels provide power, while several cover layers protect the system against extreme Mars conditions.

— Galactic Impact: Greener Cities (Gothenburg, Sweden)
The Greener Cities Project seeks to complement NASA satellite climate data with crowd-sourced microclimate data, providing higher-resolution information for monitoring the environment. The design includes a low-cost garden monitoring sensor, aggregation and normalization of local environmental data, and scaling a global educational initiative for children to encourage interest in programming and the environment.

— Most Inspiring: T-10 (London)
T-10 is a prototype mobile application for use on the International Space Station. Astronauts can program in specific points of interest they wish to photograph, and T-10 will alert them shortly before the station is set to fly over that location if the current weather permits photography. The app also can alert astronauts to interesting weather phenomena and upload photos directly to Twitter, as well as alert Earth-based users when the ISS will fly overhead.

Social media users around the world joined the judging action to vote for their favorite projects. During the event 770 solutions were submitted and 133 of those were nominated for global judging. Submissions had to include a two-minute video and be nominated by a local challenge lead to qualify for global judging. To learn more about the International Space Apps Challenge and recent winners, visit *spaceappschallenge.org*.

NASA Announces Asteroid Grand Challenge

NASA announced in June a Grand Challenge focused on finding all asteroid threats to human populations and knowing what to do about them. The challenge, which was announced at an asteroid initiative industry and partner day at NASA Headquarters in Washington, is a large-scale effort that will use multidisciplinary collaborations and a variety of partnerships with other government agencies, international partners, industry, academia, and citizen scientists. It complements NASA's recently announced mission to redirect an asteroid and send humans to study it.

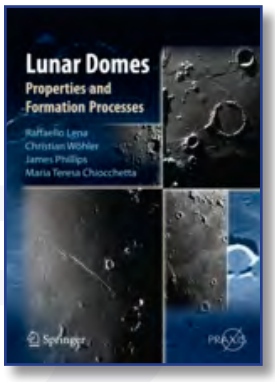
"NASA already is working to find asteroids that might be a threat to our planet, and while we have found 95 percent of the large asteroids near the Earth's orbit, we need to find all those that might be a threat to Earth," said NASA Deputy Administrator Lori Garver. "This Grand Challenge is focused on detecting and characterizing asteroids and learning how to deal with potential threats. We will also harness public engagement, open innovation, and citizen science to help solve this global problem."

Grand Challenges are ambitious goals on a national or global scale that capture the imagination and demand advances in innovation and breakthroughs in science and technology. They are an important element of President Obama's Strategy for American Innovation.

"I applaud NASA for issuing this Grand Challenge because finding asteroid threats, and having a plan for dealing with them, needs to be an all-hands-on-deck effort," said Tom Kalil, deputy director for technology and innovation at the White House Office of Science and Technology Policy. "The efforts of private-sector partners and our citizen scientists will augment the work NASA already is doing to improve near-Earth object detection capabilities."

For more information about NASA's asteroid initiative, visit *www.nasa.gov/asteroidinitiative*.

BOOKS



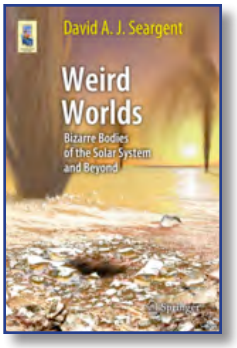
Lunar Domes: Properties and Formation Processes.

By Raffaello Leno, Christian Wöhler, James Phillips, and Maria Teresa Chiocchetta. Springer, 2013. 174 pp., Hardcover, $89.95. *www.springer.com*

Lunar domes are structures of volcanic origin that are usually difficult to observe due to their low heights. This book is a reference work on these elusive features. It provides a collection of images for a large number of lunar domes, including telescopic images acquired with advanced but still moderately intricate amateur equipment as well as recent orbital spacecraft images. Different methods for determining the morphometric properties of lunar domes (diameter, height, flank slope, edifice volume) from image data or orbital topographic data are discussed. Additionally, multispectral and hyperspectral image data are examined, providing insights into the composition of the dome material. Several classification schemes for lunar domes are described, including an approach based on the determined morphometric quantities and spectral analyses. This book also provides a description of geophysical models of lunar domes, which yield information about the properties of the lava from which they formed and the depth of the magma source regions below the lunar surface.

Weird Worlds: Bizarre Bodies of the Solar System and Beyond.

By David A. J. Seargent. Springer, 2013. 309 pp., Paperback, $34.95. *www.springer.com*



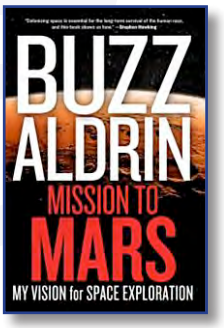
Weird Worlds is the third book in David Seargent's "Weird" series. This book assumes a basic level of astronomical understanding and concentrates on the "odd and interesting" aspects of planetary bodies, including asteroids and moons. From a viewpoint here on Earth, this work depicts the most unusual features of these worlds and the ways in which they appear "weird" to us. Within our own solar system, odd facts such as the apparent reversal of the Sun in the skies of Mercury, CO_2-driven fountains of dust on Mars, possible liquid water (and perhaps primitive life!) deep within the dwarf planet Ceres, and a variety of odd facts about the planetary moons are all discussed. A special chapter is devoted to Saturn's giant moon Titan, and its methane-based weather system and "hydrological" cycle. This chapter also includes recent speculation on the possibility of methane-based organisms and the form that these might take, if they really do exist. Beyond our solar system, the book looks at the range of worlds discovered and hypothesized.

How to Build a Habitable Planet: The Story of Earth from the Big Bang to Humankind (Revised and Expanded Edition).

By Charles H. Langmuir and Wally Broecker. Princeton University Press, 2012. 720 pp., Hardcover, $39.95. *press.princeton.edu*

Since its first publication more than 25 years ago, *How to Build a Habitable Planet* has established a legendary reputation as an accessible yet scientifically impeccable introduction to the origin and evolution of Earth, from the Big Bang through the rise of human civilization. This classic account of how our habitable planet was assembled from the stuff of stars introduced readers to planetary, Earth, and climate science by way of a fascinating narrative. Now it has been made even better. Authors Langmuir and Broecker have revised and expanded the book for a new generation of readers for whom active planetary stewardship

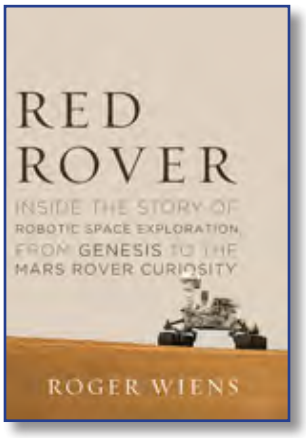
is becoming imperative. Interweaving physics, astronomy, chemistry, geology, and biology, this sweeping account tells Earth's complete story, from the synthesis of chemical elements in stars, to the formation of the solar system, to the evolution of a habitable climate on Earth, to the origin of life and humankind. The book also addresses the search for other habitable worlds in the Milky Way and contemplates whether Earth will remain habitable as our influence on global climate grows. It concludes by considering the ways in which humankind can sustain Earth's habitability and perhaps even participate in further planetary evolution.



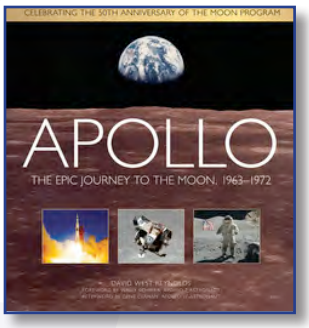
Mission to Mars: My Vision for Space Exploration.
By Buzz Aldrin. National Geographic, 2013, 272 pp., Hardcover, $26.00.
shop.nationalgeographic.com

In his latest book, Aldrin sees humans on Mars in the 2030s and boldly advocates continuing exploration of our solar system at a time when America stands at a critical crossroads in its space program. He outlines past triumphs, analyzes recent setbacks, and cheers us on to greater accomplishments with a message that will ignite a new wave of support and participation across the country for a renewed and ambitious space program. Our journeys into space can once more capture the imagination of new generations of scientists, engineers, astronauts, and the general public.

Red Rover: Inside the Story of Robotic Space Exploration, from Genesis to the Mars Rover Curiosity.
By Roger Wiens. Basic Books, 2013, 256 pp., Hardcover, $25.99. *www.basicbooks.com*



In its eerie likeness to Earth, Mars has long captured our imaginations — both as a destination for humankind and as a possible home to extraterrestrial life. It is our twenty-first century New World, its explorers robots, shipped 350 million miles from Earth to uncover the distant planet's secrets. Its most recent scout is Curiosity — a one-ton, Jeep-sized nuclear-powered space laboratory — which is now roving the martian surface to determine whether the Red Planet has ever been physically capable of supporting life. In *Red Rover,* geochemist Wiens, the principal investigator for the ChemCam laser instrument on the rover and veteran of numerous robotic NASA missions, tells the unlikely story of his involvement in sending sophisticated hardware into space, culminating in the Curiosity rover's amazing journey to Mars. Wiens paints the portrait of one of the most exciting scientific stories of our time: the new era of robotic space exploration. Starting with NASA's introduction of the Discovery Program in 1992, scrappier, more nimble missions became the order of the day, as manned missions were confined to Earth orbit, and behemoth projects went extinct. This strategic shift presented huge scientific opportunities, but tight budgets meant that success depended more than ever on creative engineering and human ingenuity. Beginning with the Genesis mission that launched his career, Wiens describes the competitive, "do-it-yourself" spirit of these robotic enterprises, from conception to construction, from launch to heart-stopping crashes and smooth landings. An inspiring account of the real-life challenges of space exploration, *Red Rover* vividly narrates what goes into answering the question: Is there life elsewhere in the universe?



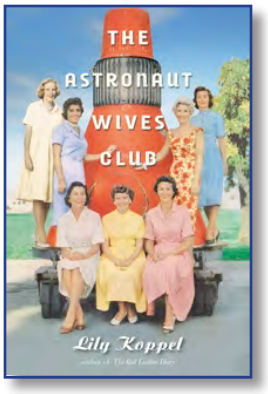
Apollo: The Epic Journey to the Moon, 1963–1972.

By David West Reynolds. Zenith Press, 2013, 272 pp., Hardcover, $40.00. *www.zenithpress.com*

Featuring a wealth of rare photographs, artwork, and cutaway illustrations, Apollo recaptures the excitement of the United States' journey to the Moon. From the adventurous astronauts to the scientists and engineers who designed and built the state-of-the-art spacecraft, Reynolds covers every aspect of this epic voyage. Through concise description, he introduces the uninitiated to this thrilling episode in U.S. history while also providing engaging details for the space aficionado. All the key events and personalities are presented, creating a clear picture of how we got to the Moon and what happened along the way. The detailed diagrams and maps give the reader an in-depth understanding of the technology that carried the astronauts to the Moon and what they accomplished while they were there. In addition, the book includes a foreword by Wally Schirra, the only astronaut to fly in all three of the Mercury, Gemini, and Apollo programs, and an afterword by Gene Cernan, the last man to walk on the Moon.

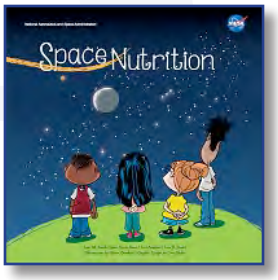
The Astronaut Wives Club: A True Story.

By Lily Koppel. Grand Central Publishing, 2013, 288 pp., Hardcover, $28.00. *www.hachettebookgroup.com*



As America's Mercury Seven astronauts were launched on death-defying missions, television cameras focused on the brave smiles of their young wives. Overnight, these women were transformed from military spouses into American royalty. They had tea with Jackie Kennedy, appeared on the cover of *Life* magazine, and quickly grew into fashion icons. Annie Glenn, with her picture-perfect marriage, was the envy of the other wives; platinum-blonde Rene Carpenter was proclaimed President John F. Kennedy's favorite; and licensed pilot Trudy Cooper arrived on base with a secret. Together with the other wives they formed the Astronaut Wives Club, meeting regularly to provide support and friendship. Many became next-door neighbors and helped to raise each other's children by day, while going to glam parties at night as the country raced to land a man on the Moon. As their celebrity rose — and as divorce and tragic death began to touch their lives — they continued to rally together, and the wives have now been friends for more than 50 years. This book tells the real story of the women who stood beside some of the biggest heroes in American history.

FOR KIDS!!!



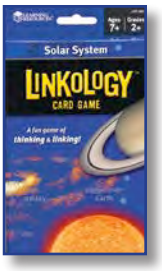
Space Nutrition.

By Scott M. Smith, Janis Davis-Street, Lisa Neasbitt, and Sara R. Zwart. Trafford Publishing, 2012. 108 pp., Paperback, $8.20. *amazon.com*

NASA's Nutritional Biochemistry Laboratory has a long and rich history of supporting education and outreach efforts. To this end, this book, aimed at upper elementary/intermediate students, highlights many aspects of space nutrition. *Space Nutrition* provides a brief history of human space flight, and details the role of nutrition throughout, from foods first eaten in space to the future of space exploration. For grades 5–8.

Linkology Solar System Card Game.

Produced by Learning Resources. $9.99. *www.learningresources.com*



Deal the cards and make the "links." Explore Earth and space science topics with this simple, fast-paced card game that is sure to become a favorite. Players match word and picture cards relating to the solar system, reinforcing key Earth and space science concepts and vocabulary. This game helps children connect broad relationships between solar system topics, covers a variety of core concepts and content, engages students with vibrant real-life photos and key solar system facts, and reinforces vocabulary and classification skills. This game can be played by up to 6 players and includes a deck of 100 self-checking photo and word cards. Great for classroom or family play. For grades 2 and up.

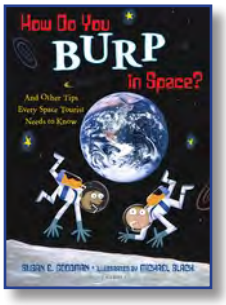
Giant Magnetic Solar System.

Produced by Learning Resources. $19.99. *www.learningresources.com*

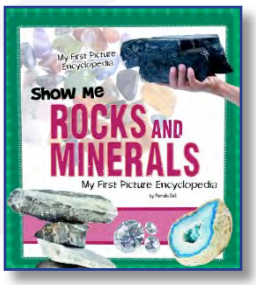
These full-color, realistically detailed magnets capture children's attention. This set includes eight planets, Pluto (dwarf planet), the Sun, our Moon, the asteroid belt, and an activity guide. The largest magnet, the Sun, measures 10 inches in diameter. For grades K and up.

How Do You Burp in Space? And Other Tips Every Space Tourist Needs to Know.

By Susan E. Goodman. Bloomsbury Children's Books, 2013. 80 pp., Hardcover, $16.99.
www.bloomsbury.com



Want to blast into orbit? Walk on the Moon? Snag a personal photo of a shooting star? Well, your time is coming, and when it does, you're going to need *How Do You Burp in Space?* This guide is filled with the kind of information you'd need to plan any vacation, including what to pack (hint: no bubble bath or juggling balls!), what to expect from your accommodations (a sleeping bag attached to the wall), and what to do for fun (leapfrog on the Moon). Grounded in the history of space travel and the planned future of space tourism, this guide book will leave young adventurers day-dreaming about future intergalactic space vacations. For ages 8 and up.



Show Me Rocks and Minerals: My First Picture Encyclopedia.

By Patricia Wooster. Capstone Press, 2014. 32 pp., Hardcover, $19.99.
www.capstonepub.com

From molten lava to glittering crystals, there's so much to learn about rocks and minerals. *Show Me Rocks and Minerals* has more than 100 facts and definitions about these amazing substances. For grades pre-K to 2.

Calendar 2013–2014

September

2–5 **Exoplanets and Brown Dwarfs: Mind the Gap,** Hatfield, UK. *http://www.star.herts.ac.uk/mindthegap/*

8–13 **European Planetary Science Conference (EPSC 2013),** London, United Kingdom. *http://www.epsc2013.eu*

9–12 **LSST @ Europe: The Path to Science,** Cambridge, United Kingdom. *http://www.lsstcorp.org/meetings/lsst-europe-2013/*

9–12 **The 11th Hellenic Astronomical Conference,** Athens, Greece. *http://www.helas.gr/conf/2013/index.php*

9–21 **The 2013 VLTI School: High Angular Resolution for Stellar Astrophysics,** Bercelonnette, France. *http://vltischool.sciencesconf.org/*

10–12 **Planet Formation and Evolution 2014,** Kiel, Germany. *http://www1.astrophysik.uni-kiel.de/~kiel2014/main/*

16–18 **Uranus Beyond Voyager 2: From Recent Advances to Future Missions,** Meudon, France. *http://uranus.sciencesconf.org*

21 **Bob Lin Memorial Symposium,** Berkeley, California. *http://boblin.ssl.berkeley.edu/*

23–24 **Origin of the Moon,** London, United Kingdom. *http://royalsociety.org/events/2013/origin-moon/*

23–26 **Polarimetry of Planetary Systems,** Florence, Italy. *http://www.polarisation.eu/index.php/meetings/polarimetry-planetary-systems*

23–27 **Improving the Performances of Current Optical Interferometers and Future Designs,** Haute-Provence Observatory, France. *http://www.obs-hp.fr/~hlecorol/workshopOHP/*

24–28 **Second International Congress of Astrobiology in Columbia,** Medellin, Columbia. *http://www.astrobiologia.org/2-congreso-internacional-de-astrobiologia.html*

25–26 **Origin of the Moon — Challenges and Prospects,** Chicheley, United Kingdom. *http://royalsociety.org/events/2013/moon-origin-satellite/*

29–Oct 4 **Sudbury Field Camp,** Sudbury, Canada. *http://www.lpi.usra.edu/nlsi/sudbury/*

30–Oct 2 **Asteroid Redirect Mission and Grand Challenge Workshop,** Houston, Texas. *http://www.nasa.gov/mission_pages/asteroids/initiative/asteroid-rfi.html#.Ueg49rYtaao*

October

3–4 **Workshop on Golden Spike Lunar Human Expeditions: Opportunities for Intensive Lunar Scientific Exploration,** Houston, Texas. *http://www.hou.usra.edu/meetings/gs2013/*

6–11 **45th Meeting of the American Astronomical Society Division for Planetary Sciences (DPS 2013),** Denver, Colorado. *http://aas.org/meetings/45th-meeting-division-planetary-sciences*

7–11 **Third Workshop on Robotic Autonomous Observatories,** Torremolinos, Spain. *http://astrorob.iaa.es/*

7–11 **Astrophysical Turbulence: From Galaxies to Planets,** Dresden, Germany. *http://www.pks.mpg.de/~aturb13/*

7–11 **ESO/NUVA/IAG Workshop on Challenges in UV Astronomy,** Garching, Germany. *http://www.eso.org/sci/meetings/2013/UVAstro2013/rationale.html*

12 **Io Workshop 2013,** Boulder, Colorado. *http://www.boulder.swri.edu/~con/ioworkshop2013/Home.html*

14–16 **Annual Meeting of the Lunar Exploration Analysis Group,** Laurel, Maryland. *http://www.hou.usra.edu/meetings/leag2013/*

14–18 **Fourth Moscow International Solar System Symposium (4M-S3),** Moscow, Russia. *http://ms2013.cosmos.ru/*

14–18 **Communicating Astronomy with the Public 2013 (CAP 2013),** Warsaw, Poland. *http://www.communicatingastronomy.org/cap2013/index.html*

15–18 **The (F)IR Universe Three Years Later — The Contributions by Herschel,** Noordwijk, The Netherlands. *http://herschel.esac.esa.int/The_FIR_Universe.shtml*

16–18 **Hayabusa 2013: Symposium of Solar System Materials,** Sagamihara, Japan. *http://hayabusaao.isas.jaxa.jp/symposium/*

20–25 **Planet Mars 4,** Les Houches, France. *http://www.sciops.esa.int/mars4*

21–23 **Solar System Formation and Observation Conference (SFO),** Bern, Switzerland. *http://sfo.unibe.ch/*

21–24 **Venus Express VIRTIS and VMC Data Workshop,** Madrid, Spain. *http://www.rssd.esa.int/index.php?project=PSA&page=vex_workshop*

27–29 **Workshop on Planetesimal Formation and Differentiation,** Washington, DC. *http://www.hou.usra.edu/meetings/planetesimal2013*

27–30 **2013 GSA Annual Meeting and Exposition,** Denver, Colorado. *http://www.geosociety.org/meetings/2013/*

November

4–8 **Second Kepler Science Conference,** Moffett Field, California. *http://kepler.arc.nasa.gov/Science/keplerconference*

5–7 **Optical Characterization of Atmospheric Aerosols Workshop,** Smolenice, Slovak Republic. *http://www.ocaa2013.sav.sk/*

11–14 **Second Exobiology Workshop,** Frejus, France. *http://www.exobiologie.fr/index.php/actualites/evenements/rencontres-sfe-2012/*

11–15 **First COSPAR Symposium: Planetary Systems of Our Sun and Other Stars, and the Future of Space Astronomy,** Bangkok, Thailand. *www.cospar2013.gistda.or.th*

19–21 **Young Researchers Exobiology Conference (EJC'13),** Paris, France. *http://www.exobiologie.fr/index.php/actualites/congres/congres-exobio-jeunes-chercheurs-2013-les-inscriptions-sont-ouvertes/*

19–21 **11th Meeting of the Venus Exploration Analysis Group (VEXAG 11),** Washington, DC. *http://www.lpi.usra.edu/vexag/*

December

8–12 **Exoplanets and Disks: Their Formation and Diversity,** Keauhou Kona, Hawaii. *http://exoplanets.astron.s.u-tokyo.ac.jp/SubaruConf13/*

9–13 **ASTROBIO 2013: An International Workshop on Astrobiology,** Santiago, Chile. *http://astrobiology2.arc.nasa.gov/events/astrobio-2013-an-international-workshop-on-astrobiology/*

9–13 **AGU Fall Meeting,** San Francisco, California. *http://fallmeeting.agu.org/2013/*

January 2014

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

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

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

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

February

5–7 **Vesta in the Light of Dawn First Exploration of a Protoplanet in the Asteroid Belt,** Houston, Texas. *http://www.hou.usra.edu/meetings/vesta2014/*

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

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

March

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

17–21 **45th Lunar and Planetary Science Conference,** The Woodlands, Texas. *http://www.hou.usra.edu/meetings/lpsc2014*

17–21 **Search for Life Beyond the Solar System — Exoplanets, Biomarkers and Instruments,** Tucson, Arizona. *http://www.ebi2014.org*

April

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

June

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

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

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