The year 2014–2105 is shaping up to be one of the most interesting in the history of solar system exploration. 2015 will feature the first-ever exploration of so-called dwarf planets (Ceres and Pluto; more on that in a future issue), but 2014 starts things off with two major cometary events. The first is the ongoing rendezvous of the European Space Agency’s (ESA) Rosetta mission with an active comet, the other is a rare cometary close encounter last month with a major planet, Mars. For more details about public events related to the encounters, see Spotlight on Education on page 27.

Rosetta has been in “orbit” around Comet 67P/Churyumov-Gerasimenko (67P/C-G for short) since August, returning exquisite unprecedented high-resolution imaging and data. As the spacecraft slowly moves closer, it has been scouting out landing sites for its small landing vehicle, Philae, in the first-ever attempt at a soft touchdown on a comet. ESA has given the green light for its Rosetta mission to deliver its lander to the primary site on Comet 67P/C-G on November 12. Philae’s landing site, currently known as Site J and located on the smaller of the comet’s two “lobes,” was confirmed on October 14 following a comprehensive readiness review.

Since arrival, the mission has been conducting an unprecedented survey and scientific analysis of the comet, which is a remnant of the early phases of the solar system’s 4.6-billion-year history. At the same time, Rosetta has been moving closer to the comet: At a distance of 100 kilometers (62 miles) on August 6, it is now just 10 kilometers (6.2 miles) from the center of the 4-kilometer-wide (2.5-mile-wide) body. This proximity allowed a more detailed look at the primary and backup landing sites in order to complete a hazard assessment, including a detailed boulder census.

This image of the surface of Comet 67P/C-G was taken by Rosetta’s OSIRIS narrow-angle camera on September 19, 2014, from a distance of 28.5 kilometers (17.7 miles) and features a 45-meter-wide (148-foot-wide) boulder casting a long shadow on the surface of the comet. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.
The decision that the mission is “Go” for Site J also confirms the timeline of events leading up to the landing. Rosetta will release Philae at 08:35 GMT/09:35 CET on November 12 at a distance of approximately 22.5 kilometers (14 miles) from the center of the comet. Landing will be about seven hours later, at around 15:30 GMT/16:30 CET. With a one-way signal travel time between Rosetta and Earth on November 12 of 28 minutes 20 seconds, confirmation of separation should arrive on Earth ground stations at 09:03 GMT/10:03 CET and confirmation of touchdown at around 16:00 GMT/17:00 CET.

“Now that we know where we are definitely aiming for, we are an important step closer to carrying out this exciting — but high-risk — operation,” says Fred Jansen, ESA’s Rosetta mission manager. “However, there are still a number of key milestones to complete before we can give the final ‘Go’ for landing.”

A series of “Go”/“No-Go” decisions must be taken before separation, starting on November 11, with a confirmation from the flight dynamics team that Rosetta is on the right trajectory ahead of lander delivery. Further “Go”/“No-Go” decisions will be made during the night of November 11–12 concerning readiness and uplink of commands, culminating in confirmation of the lander readiness for separation. A short maneuver must then take place around two hours before separation. This will set Rosetta on course to release Philae on the right trajectory to land on the comet. The final critical “Go”/“No-Go” for separation occurs shortly after this maneuver.

After the release of Philae, Rosetta will maneuver up and away from the comet, before reorienting itself in order to establish communications with Philae. “If any of the decisions result in a ‘No-Go,’ then we will have to abort and revise the timeline accordingly for another attempt, making sure that Rosetta is in a safe position to try again,” says Jansen.

If all goes well, Rosetta and its lander will begin communications about two hours after separation. During the seven-hour descent, Philae will take images and conduct science experiments, sampling the dust, gas, and plasma environment close to the comet. It will take a “farewell” image of the Rosetta orbiter shortly after separation, along with a number of images as it approaches the comet surface. It is expected that the first images from this sequence will be received on Earth several hours after separation.

Once safely on the surface, Philae will take a panorama of its surroundings, which is also expected to arrive back on Earth several hours later. The first sequence of surface science experiments will begin about an hour after touchdown and will last for 64 hours, constrained by the lander’s primary battery lifetime. Longer-term study of the comet by Philae will be dependent on how well the batteries are able to recharge and for how long, which in turn is related to the amount of dust that settles on its solar panels.
**Year of the Comets continued...**

This infographic summarizes the measurements that will be carried out by Rosetta’s lander, Philae, during its seven-hour descent to Comet 67P/C-G and immediately after touchdown. The time the signal is expected on Earth to confirm separation and approximate time of landing confirmation is also provided. Lander operations are listed in alphabetical order. After touchdown measurements have been made, the lander will begin the first science sequence operations (not shown here). Credit: ESA/ATG Medialab.
In any case, it is expected that by March 2015, as the comet moves closer in its orbit toward the Sun, temperatures inside the lander will have reached levels too high to continue operations, and Philae’s science mission will come to an end. But the Rosetta orbiter’s mission will continue for much longer. It will accompany the comet as it grows in activity until their closest approach to the Sun in August 2015, and then as they head back toward the outer solar system.

This unprecedented mission will study how a comet evolves with distance from the Sun and will provide important insights into the formation of our solar system, as well as the origins of water and perhaps even life on Earth.

Images of Comet 67P/C-G taken on approach by the OSIRIS imaging system onboard Rosetta have also allowed scientists to create a three-dimensional shape model of the nucleus (http://photojournal.jpl.nasa.gov/catalog/PIA18419). The shape model can be downloaded and used in a 3-D printer to create your own comet model. The high-resolution mapping will allow even more detailed models to be produced in the future.

By the time you read this article, another major comet event will have already occurred. Planet Earth’s extensive fleet of science assets, particularly those orbiting and roving Mars, had front row seats to image and study a once-in-a-lifetime comet flyby on Sunday, October 19. Comet C/2013 A1, also known...
as Comet Siding Spring, passed within about 139,500 kilometers (87,000 miles) of the Red Planet — less than half the distance between Earth and our Moon and less than one-tenth the distance of any known comet flyby of Earth.

Siding Spring’s nucleus came closest to Mars around 2:27 p.m. Eastern Daylight Time (EDT), hurtling at about 56 kilometers per second (126,000 miles per hour). This proximity provided an unprecedented opportunity for researchers to gather data on both the comet and its effect on the martian atmosphere.

“This is a cosmic science gift that could potentially keep on giving, and the agency’s diverse science missions will be in full receive mode,” said John Grunsfeld, astronaut and associate administrator for NASA’s Science Mission Directorate in Washington. “This particular comet has never before entered the inner solar system, so it will provide a fresh source of clues to our solar system’s earliest days.”

Siding Spring came from the Oort cloud, a spherical region of space surrounding our Sun and occupying space at a distance between 5000 and 100,000 astronomical units. It is a giant swarm of icy objects believed to be material left over from the formation of the solar system. Siding Spring will be the first comet from the Oort cloud to be studied up close by spacecraft, giving scientists an invaluable opportunity to learn more about the materials, including water and carbon compounds, that existed during the formation of the solar system 4.6 billion years ago.

Some of the best and most revealing images and science data will come from assets orbiting and roving the surface of Mars.

In preparation for the comet flyby, NASA maneuvered its Mars Odyssey orbiter, Mars Reconnaissance Orbiter (MRO), and the newest member of the Mars fleet, Mars Atmosphere and Volatile EvolutioN (MAVEN), in order to reduce the risk of impact with high-velocity dust particles coming off the comet. Europe’s Mars Express and India’s Mars Orbiter Mission also prepared and had excellent views of the passing comet.
Year of the Comets continued . . .

The period of greatest risk to orbiting spacecraft started about 90 minutes after the closest approach of the comet’s nucleus and lasted about 20 minutes, when Mars came closest to the center of the widening trail of dust flying from the comet’s nucleus. “The hazard is not an impact of the comet nucleus itself, but the trail of debris coming from it. Using constraints provided by Earth-based observations, the modeling results indicate that the hazard is not as great as first anticipated. Mars will be right at the edge of the debris cloud, so it might encounter some of the particles — or it might not,” said Richard Zurek, chief scientist for the Mars Exploration Program at NASA’s Jet Propulsion Laboratory (JPL) in Pasadena, California, when discussing the anticipated event.

Hubble Space Telescope image of Comet Siding Springs taken by the Wide Field Camera 3. The nucleus is too small to be resolved. Credit: NASA.

NASA’s NEOWISE mission previously captured images of Comet Siding Spring. The infrared pictures reveal a comet that is active and very dusty even though it was about 571 million kilometers (355 million miles) away from the Sun on January 16, 2014, when this picture was taken. Infrared measurements allow astronomers to determine the sizes and quantity of dust particles being flung off the comet. Credit: NASA/JPL-Caltech.
The atmosphere of Mars, although much thinner than Earth’s, should shield NASA Mars rovers Opportunity and Curiosity from comet dust, if any reached the planet. Both rovers were scheduled to make observations of the comet. NASA’s Mars orbiters gathered information before, during, and after the flyby about the size, rotation, and activity of the comet’s nucleus, the variability and gas composition of the coma around the nucleus, and the size and distribution of dust particles in the comet’s tail.

Observations of the martian atmosphere were designed to check for possible meteor trails, changes in distribution of neutral and charged particles, and effects of the comet on air temperature and clouds. MAVEN had a particularly good opportunity to study the comet, and how its tenuous atmosphere, or coma, interacts with Mars’ upper atmosphere.

Earth-based and space telescopes, including NASA’s iconic Hubble Space Telescope, were also in position to observe the unique celestial object. The agency’s astrophysics space observatories — Kepler, Swift, Spitzer, Chandra — and the ground-based Infrared Telescope Facility on Mauna Kea, Hawaii, also tracked the event.

NASA’s asteroid hunter, the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), has been imaging, and will continue to image, the comet as part of its operations. And the agency’s two heliophysics spacecraft, the Solar TErrestrial RElations Observatory (STEREO) and Solar and Heliophysics Observatory (SOHO), also imaged the comet. The agency’s Balloon Observation Platform for Planetary Science (BOPPS), a suborbital balloon-carried telescope, has already provided observations of the comet in the lead-up to the close encounter with Mars.

Images and updates will be posted online following the comet flyby. Several pre-flyby images of Siding Spring, as well as information about the comet and NASA’s planned observations of the event, are available online at http://mars.nasa.gov/comets/sidingspring.

Late-Breaking News —
As of October 21, all Mars-orbiting spacecraft reported back healthy, and many of them are returning images. The spacecraft with the most powerful imaging camera, the High Resolution Imaging Science Experiment (HiRISE) on NASA’s Mars Reconnaissance Orbiter, successfully captured images of Oort cloud Comet C/2013 A1 Siding Spring from a minimum distance of about 138,000 kilometers (86,000 miles). HiRISE acquired images 12 days earlier that indicated the comet was not quite at its predicted location. This information was used to update targeting at closest approach. The best images have a resolution of 138 meters (150 yards) per pixel and show only 2 to 3 pixels across what is probably the nucleus, suggesting a size of less than 0.4 kilometers (0.25 miles) across. Additional processing may reveal more details, and more data will be returned over the coming days.
**About the Cover**

This image captures the side of the Rosetta spacecraft and one of its 14-meter-long (46-foot-long) solar wings, with Comet 67P/Churyumov-Gerasimenko visible in the background at a distance of 16 kilometers (10 miles). Two photos with different exposure times were combined to bring out the faint details. The comet's active neck region is clearly visible, with streams of dust and gas extending away from the surface. Credit: ESA/Rosetta/Philae/CIVA.
NASA Mission Points to Origin of “Ocean of Storms” on Earth’s Moon

Using data from NASA’s Gravity Recovery and Interior Laboratory (GRAIL), mission scientists have solved a lunar mystery almost as old as the Moon itself. Early theories suggested the craggy outline of a region of the Moon’s surface known as Oceanus Procellarum, or the Ocean of Storms, was caused by an asteroid impact. If this theory had been correct, the basin it formed would be the largest asteroid impact basin on the Moon. However, mission scientists studying GRAIL data believe they have found evidence that the craggy outline of this rectangular region—roughly 2600 kilometers (1600 miles) across—is actually the result of the formation of ancient rift valleys.

“The nearside of the Moon has been studied for centuries, and yet continues to offer up surprises for scientists with the right tools,” said Maria Zuber, principal investigator of NASA’s GRAIL mission, from the Massachusetts Institute of Technology, Cambridge. “We interpret the gravity anomalies discovered by GRAIL as part of the lunar magma plumbing system—the conduits that fed lava to the surface during ancient volcanic eruptions.”

The surface of the Moon’s nearside is dominated by a unique area called the Procellarum region, characterized by low elevations, unique composition, and numerous ancient volcanic plains. The rifts are buried beneath dark volcanic plains on the nearside of the Moon and have been detected only in the gravity data provided by GRAIL. The lava-flooded rift valleys are unlike anything found anywhere else on the Moon and may at one time have resembled rift zones on Earth, Mars, and Venus. The findings are published online in the journal Nature.

Another theory arising from recent data analysis suggests this region formed as a result of churning deep in the interior of the Moon that led to a high concentration of heat-producing radioactive elements in the crust and mantle of this region. Scientists studied the gradients in gravity data from GRAIL, which revealed a rectangular shape in resulting gravitational anomalies.

“The rectangular pattern of gravity anomalies was completely unexpected,” said Jeff Andrews-Hanna, a GRAIL co-investigator at the Colorado School of Mines in Golden, Colorado, and lead author of the paper. “Using the gradients in the gravity data to reveal the rectangular pattern of anomalies, we can now clearly and completely see structures that were only hinted at by surface observations.”
The rectangular pattern, with its angular corners and straight sides, contradicts the theory that Procellarum is an ancient impact basin, since such an impact would create a circular basin. Instead, the new research suggests processes beneath the Moon’s surface dominated the evolution of this region. Over time, the region would cool and contract, pulling away from its surroundings and creating fractures similar to the cracks that form in mud as it dries out, but on a much larger scale.

The study also noted a surprising similarity between the rectangular pattern of structures on the Moon, and those surrounding the south polar region of Saturn’s icy Moon Enceladus. Both patterns appear to be related to volcanic and tectonic processes operating on their respective worlds.

“Our gravity data are opening up a new chapter of lunar history, during which the Moon was a more dynamic place than suggested by the cratered landscape that is visible to the naked eye.” said Andrews-Hanna. “More work is needed to understand the cause of this newfound pattern of gravity anomalies, and the implications for the history of the Moon.”

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 55 kilometers (34 miles) 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.

For more information, visit [www.nasa.gov/grail](http://www.nasa.gov/grail).

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**Mars Orbiter Spacecraft Successfully Inserted into Mars Orbit**

India’s Mars Orbiter Spacecraft successfully entered orbit around Mars on September 24 by firing its 440-Newton Liquid Apogee Motor (LAM) along with eight smaller liquid engines. The liquid engines firing operation, which began at 07:17:32 Hrs IST, lasted for 1388.67 seconds, changing the velocity of the spacecraft by 1099 meters (3606 feet) per second. Upon completing this operation, the spacecraft entered into an elliptical orbit around Mars. The Honorable Prime Minister of India, Mr. Narendra Modi, was present at the Indian Space Research Organization’s (ISRO) Telemetry, Tracking, and Command Network (ISTRAC) in Bangalore to witness the important event.

The image of regional dust storm activities over the northern hemisphere of Mars was captured by the color camera onboard India's Mars Orbiter Spacecraft from an altitude of 74,500 kilometers (46,292 miles) on September 28, 2014. Credit: ISRO.
News from Space continued . . .

All events related to Mars orbit insertion progressed satisfactorily, and the spacecraft performance was normal. The spacecraft is now circling Mars in an orbit whose nearest point to Mars (periapsis) is at 421.7 kilometers (262 miles) and farthest point (apoapsis) is 76,993.6 kilometers (47,841 miles). The inclination of orbit with respect to the equatorial plane of Mars is 150°, as intended. In this orbit, the spacecraft takes 72 hours 51 minutes 51 seconds to go around Mars once.

The Mars Orbiter Spacecraft, also known as Mangalyaan, was launched onboard India’s PSLV launch vehicle on November 5, 2013, into a parking orbit around Earth. On December 1, 2013, following a trans-Mars injection (TMI) maneuver, the spacecraft escaped from Earth’s orbit followed a path that allowed it to encounter Mars on September 24, 2014.

With the successful Mars orbit insertion operation, ISRO has become the fourth space agency to successfully send a spacecraft to Mars orbit. Subsequent to orbit insertion, the spacecraft is being thoroughly tested in Mars orbit and the systematic observation of that planet using its five scientific instruments will begin.

NASA’s Newest Mars Mission Spacecraft Enters Orbit Around Red Planet

NASA’s Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft successfully entered Mars’ orbit at 7:24 p.m. Pacific Daylight Time (PDT) on Sunday, September 21, where it now will prepare to study the Red Planet’s upper atmosphere as never before. MAVEN is the first spacecraft dedicated to exploring the tenuous upper atmosphere of Mars. “As the first orbiter dedicated to studying Mars’ upper atmosphere, MAVEN will greatly improve our understanding of the history of the martian atmosphere, how the climate has changed over time, and how that has influenced the evolution of the surface and the potential habitability of the planet,” said NASA Administrator Charles Bolden. “It also will better inform a future mission to send humans to the Red Planet in the 2030s.”

After a 10-month journey, confirmation of successful orbit insertion was received from MAVEN data observed at the Lockheed Martin operations center in Littleton, Colorado, as well as from tracking data monitored at NASA’s Jet Propulsion Laboratory navigation facility in Pasadena, California. The telemetry and tracking data were received by NASA’s Deep Space Network antenna station in Canberra, Australia. “NASA has a long history of scientific discovery at Mars and the safe arrival of MAVEN opens another chapter,” said John Grunsfeld, astronaut and associate administrator of the NASA Science Mission Directorate at the agency’s Headquarters in Washington. “MAVEN will complement NASA’s other
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martian robotic explorers — and those of our partners around the globe — to answer some fundamental questions about Mars and life beyond Earth.”

Following orbit insertion, MAVEN began a six-week commissioning phase that includes maneuvering into its final science orbit and testing the instruments and science-mapping commands. MAVEN then began its one-Earth-year primary mission, taking measurements of the composition, structure, and escape of gases in Mars’ upper atmosphere and its interaction with the Sun and solar wind. “It’s taken 11 years from the original concept for MAVEN to now having a spacecraft in orbit at Mars,” said Bruce Jakosky, MAVEN principal investigator with the Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder. “I’m delighted to be here safely and successfully, and looking forward to starting our science mission.”

The primary mission includes five “deep-dip” campaigns, in which MAVEN’s periapsis, or lowest orbit altitude, will be lowered from 150 kilometers (93 miles) to about 125 kilometers (77 miles). These measurements will provide information down to where the upper and lower atmospheres meet, giving scientists a full profile of the upper tier. For more information, visit www.nasa.gov/maven or mars.nasa.gov/maven.

Curiosity Rover Arrives at Martian Mountain

NASA’s Mars Curiosity rover has reached the Red Planet’s Mount Sharp, a Mount-Rainier-sized mountain at the center of the vast Gale Crater and the rover mission’s long-term prime destination. “Curiosity now will begin a new chapter from an already outstanding introduction to the world,” said Jim Green, director of NASA’s Planetary Science Division at NASA Headquarters in Washington. “After a historic and innovative landing along with its successful science discoveries, the scientific sequel is upon us.”

Curiosity’s trek up the mountain will begin with an examination of the mountain’s lower slopes. The rover is starting this process at an entry point near an outcrop called Pahrump Hills, rather than continuing on to the previously planned, further entry point known as Murray Buttes. Both entry points lay along a boundary where the southern base layer of the mountain meets crater-floor deposits washed down from the crater’s northern rim. “It has been a long but historic journey to this martian mountain,” said Curiosity Project Scientist John Grotzinger of the California Institute of Technology in Pasadena. “The nature of the terrain at Pahrump Hills and just beyond it is a better place than Murray Buttes to learn about the significance of this contact. The exposures at the contact are better due to greater topographic relief.”
The decision to head uphill sooner, instead of continuing to Murray Buttes, also draws from improved understanding of the region’s geography provided by the rover’s examinations of several outcrops during the past year. Curiosity currently is positioned at the base of the mountain along a pale, distinctive geological feature called the Murray formation. Compared to neighboring crater-floor terrain, the rock of the Murray formation is softer and does not preserve impact scars as well. As viewed from orbit, it is not as well layered as other units at the base of Mount Sharp.

Curiosity made its first close-up study last month of two Murray formation outcrops, both revealing notable differences from the terrain explored by Curiosity during the past year. The first outcrop, called Bonanza King, proved too unstable for drilling, but was examined by the rover’s instruments and determined to have high silicon content. A second outcrop, examined with the rover’s telephoto Mast Camera, revealed a fine-grained, platy surface laced with sulfate-filled veins. While some of these terrain differences are not apparent in observations made by NASA’s Mars orbiters, the rover team still relies heavily on images taken by the agency’s Mars Reconnaissance Orbiter (MRO) to plan Curiosity’s travel routes and locations for study.

Curiosity reached its current location after its route was modified earlier this year in response to excessive wheel wear. In late 2013, the team realized a region of martian terrain littered with sharp, embedded rocks was poking holes in four of the rover’s six wheels. This damage accelerated the rate of wear and tear beyond that for which the rover team had planned. In response, the team altered the rover’s route to a milder terrain, bringing the rover farther south, toward the base of Mount Sharp.

“The wheels issue contributed to taking the rover farther south sooner than planned, but it is not a factor in the science-driven decision to start ascending here rather than continuing to Murray Buttes first,” said Jennifer Trosper, Curiosity Deputy Project Manager at NASA’s Jet Propulsion Laboratory in Pasadena, California. “We have been driving hard for many months to reach the entry point to Mount Sharp,” Trosper said. “Now that we’ve made it, we’ll be adjusting the operations style from a priority on driving to a priority on conducting the investigations needed at each layer of the mountain.”

After landing inside Gale Crater in August 2012, Curiosity fulfilled its major science goal of determining whether Mars ever offered environmental conditions favorable for microbial life. Clay-bearing sedimentary rocks on the crater floor, in an area called Yellowknife Bay, yielded evidence of a lake-bed environment billions of years ago that offered fresh water, all the key elemental ingredients for life, and a chemical source of energy for microbes.

For more information, visit mars.jpl.nasa.gov/msl.

U.S., India to Collaborate on Mars Exploration, Earth-Observing Mission

In a meeting in Toronto on September 30, NASA Administrator Charles Bolden and K. Radhakrishnan, chairman of the Indian Space Research Organisation (ISRO), signed two documents to launch a NASA-ISRO satellite mission to observe Earth and establish a pathway for future joint missions to explore Mars.

While attending the International Astronautical Congress, the two space agency leaders met to discuss and sign a charter that establishes a NASA-ISRO Mars Working Group to investigate enhanced cooperation between the two countries in Mars exploration. They also signed an international agreement that defines
how the two agencies will work together on the NASA-ISRO Synthetic Aperture Radar (NISAR) mission, targeted to launch in 2020.

“The signing of these two documents reflects the strong commitment NASA and ISRO have to advancing science and improving life on Earth,” said NASA Administrator Charles Bolden. “This partnership will yield tangible benefits to both our countries and the world.”

The joint Mars Working Group will seek to identify and implement scientific, programmatic and technological goals that NASA and ISRO have in common regarding Mars exploration. The group will meet once a year to plan cooperative activities, including potential NASA-ISRO cooperation on future missions to Mars.

Both agencies have newly arrived spacecraft in Mars orbit. NASA’s Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft arrived at Mars on September 21. MAVEN is the first spacecraft dedicated to exploring the tenuous upper atmosphere of Mars. ISRO’s Mars Orbiter Mission (MOM), India’s first spacecraft launched to Mars, arrived on September 24 to study the martian surface and atmosphere and demonstrate technologies needed for interplanetary missions. One of the working group’s objectives will be to explore potential coordinated observations and science analysis between MAVEN and MOM, as well as other current and future Mars missions.

The joint NISAR Earth-observing mission will make global measurements of the causes and consequences of land surface changes. Potential areas of research include ecosystem disturbances, ice sheet collapse and natural hazards. The NISAR mission is optimized to measure subtle changes of the Earth’s surface associated with motions of the crust and ice surfaces. NISAR will improve our understanding of key impacts of climate change and advance our knowledge of natural hazards.

NASA and ISRO have been cooperating under the terms of a framework agreement signed in 2008. This cooperation includes a variety of activities in space sciences such as two NASA payloads — the Mini-Synthetic Aperture Radar (Mini-SAR) and the Moon Mineralogy Mapper — on ISRO’s Chandrayaan-1 mission to the Moon in 2008. During the operational phase of this mission, the Mini-SAR instrument detected ice deposits near the Moon’s northern pole.
Scientists Find Evidence of “Diving” Tectonic Plates on Europa

Scientists have found evidence of plate tectonics on Jupiter’s moon Europa. This indicates the first sign of this type of surface-shifting geological activity on a world other than Earth.

Researchers have clear visual evidence of Europa’s icy crust expanding. However, they could not find areas where the old crust was destroyed to make room for the new. While examining Europa images taken by NASA’s Galileo orbiter in the early 2000s, planetary geologists Simon Kattenhorn, of the University of Idaho, Moscow, and Louise Prockter, of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, discovered some unusual geological boundaries. “We have been puzzled for years as to how all this new terrain could be formed, but we couldn’t figure out how it was accommodated,” said Prockter. “We finally think we’ve found the answer.”

Plate tectonics is the scientific theory that Earth’s outer layer is made up of plates or blocks that move, which accounts for why mountains and volcanos form and earthquakes happen. The surface of Europa — one of Jupiter’s four largest moons and slightly smaller than Earth’s Moon — is riddled with cracks and ridges. Surface blocks are known to have shifted in the same way blocks of Earth’s outer ground layer on either side of the San Andreas fault move past each in California. Many parts of Europa’s surface show evidence of extension, where bands miles wide formed as the surface ripped apart and fresh icy material from the underlying shell moved into the newly created gap — a process akin to seafloor spreading on Earth.

On Earth, as new surface material forms at mid-ocean ridges, old material is destroyed at subduction zones, which are regions where two tectonic plates converge and overlap as one is forced under the other.

This conceptual illustration of the subduction process (where one plate is forced under another) shows how a cold, brittle, outer portion of Europa’s 20–30-kilometer-thick (roughly 10–20-mile) ice shell moved into the warmer shell interior and was ultimately subsumed. A low-relief subsumption band was created at the surface in the overriding plate, alongside which cryolavas may have erupted. Credit: Noah Kroese, I.NK.
However, despite the degree of extension evident on Europa’s surface, researchers had not been able to determine how the surface could accommodate all the new material. Scientists studying Europa often reconstruct the moon’s surface blocks into their original configuration — as with a jigsaw puzzle — to get a picture of what the surface looked like before the disruption occurred. When Kattenhorn and Prockter rearranged the icy terrain in the images, they discovered that nearly 20,000 square kilometers (more than 12,000 square miles) of the surface were missing in the moon’s high northern latitudes.

Further evidence suggested the missing terrain moved under a second surface plate — a scenario commonly seen on Earth at plate-tectonic boundaries. Kattenhorn and Prockter saw ice volcanos on the overriding plate, possibly formed through melting and absorption of the slab as it dove below the surface, and a lack of mountains at the subduction zone, implying material was pushed into the interior rather than crumpled up as the two plates mashed against each other. The scientists believe the subducted area was absorbed into Europa’s ice shell, which may be up to 30 kilometers (20 miles) thick, rather than breaking through it into Europa’s underlying ocean. On Europa’s relatively young surface — about 40–90 million years old, on average — scientists have seen evidence of material moving up from under the shell but, until now, no mechanism had been found for moving material back into the shell, and possibly into the large ocean below the ice.

“Europa may be more Earth-like than we imagined, if it has a global plate tectonic system,” Kattenhorn says. “Not only does this discovery make it one of the most geologically interesting bodies in the solar system, it also implies two-way communication between the exterior and interior — a way to move material from the surface into the ocean — a process which has significant implications for Europa’s potential as a habitable world.”

The team’s results appeared in an online edition of the journal Nature Geoscience.

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**Swirling Cloud at Titan’s Pole is Cold and Toxic**

Scientists analyzing data from NASA’s Cassini mission have discovered that a giant, toxic cloud is hovering over the south pole of Saturn’s largest moon, Titan, after the atmosphere there cooled dramatically. The scientists found that this giant polar vortex contains frozen particles of the toxic compound hydrogen cyanide, or HCN.

“The discovery suggests that the atmosphere of Titan’s southern hemisphere is cooling much faster than we expected,” said Remco de Kok of Leiden Observatory and SRON Netherlands Institute for Space Research, lead author of the study published in the journal Nature.
Titan is the only moon in the solar system that is cloaked in a dense atmosphere. Like our home planet, Earth, Titan experiences seasons. As it makes its 29-year orbit around the Sun along with Saturn, each season lasts about seven Earth years. The most recent seasonal switch occurred in 2009, when winter gave way to spring in the northern hemisphere, and summer transitioned to autumn in the southern hemisphere.

In May 2012, while Titan’s southern hemisphere was experiencing autumn, images from Cassini revealed a huge swirling cloud, several hundred miles across, taking shape above Titan’s south pole. This polar vortex appears to be an effect of the change of season. A puzzling detail about the swirling cloud is its altitude, approximately 300 kilometers (about 200 miles) above Titan’s surface, where scientists thought the temperature was too warm for clouds to form. “We really didn’t expect to see such a massive cloud so high in the atmosphere,” said de Kok.

Keen to understand what could give rise to this mysterious cloud, the scientists dove into Cassini’s observations and found an important clue in the spectrum of sunlight reflected by Titan’s atmosphere. A spectrum splits the light from a celestial body into its constituent colors, revealing signatures of the elements and molecules present. Cassini’s visual and infrared mapping spectrometer (VIMS) maps the distribution of chemical compounds in Titan’s atmosphere and on its surface. “The light coming from the polar vortex showed a remarkable difference with respect to other portions of Titan’s atmosphere,” says de Kok. “We could clearly see a signature of frozen HCN molecules.”

As a gas, HCN is present in small amounts in the nitrogen-rich atmosphere of Titan. Finding these molecules in the form of ice was surprising, as HCN can condense to form frozen particles only if the atmospheric temperature is as cold as –148°C (–234°F). This is about 100°C (about 200°F) colder than predictions from current theoretical models of Titan’s upper atmosphere.

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

**NASA Experiments Recreate Aromatic Flavors of Titan**

NASA scientists have created a new recipe that captures key flavors of the brownish-orange atmosphere around Saturn’s largest moon, Titan. The recipe is used for lab experiments designed to simulate Titan’s chemistry. With this approach, the team was able to classify a previously unidentified material discovered by NASA’s Cassini spacecraft in the moon’s smoggy haze. “Now we can say that this material has a strong aromatic character, which helps us understand more about the complex mixture of molecules that makes up Titan’s haze,” said Melissa Trainer, a planetary scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

The material had been detected earlier in data gathered by Cassini’s Composite Infrared Spectrometer, an instrument that makes observations at wavelengths in the far-infrared region, beyond red light. The spectral signature of the material suggested it was made up of a mixture of molecules. To investigate that mixture, the researchers turned to the tried-and-true approach of combining gases in a chamber and letting them react. The idea is that if the experiment starts with the right gases and under the right conditions, the reactions in the lab should yield the same products found in Titan’s smoggy atmosphere. The process is like being given a slice of cake and trying to figure out the recipe by tasting it. If you can make a cake that tastes like the original slice, then you chose the right ingredients.
The challenge is that the possibilities are almost limitless in this case. Titan’s dirty orange color comes from a mixture of hydrocarbons (molecules that contain hydrogen and carbon) and nitrogen-carrying chemicals called nitriles. The family of hydrocarbons already has hundreds of thousands of members, identified from plants and fossil fuels on Earth, and more could exist. The logical starting point was to begin with the two gases most plentiful in Titan’s atmosphere: nitrogen and methane. But these experiments never produced a mixture with a spectral signature to match to the one seen by Cassini; neither have similar experiments conducted by other groups. Promising results finally came when the researchers added a third gas, essentially tweaking the flavors in the recipe for the first time. The team began with benzene, which has been identified in Titan’s atmosphere, followed by a series of closely related chemicals that are likely to be present there. All these gases belong to the subfamily of hydrocarbons known as aromatics.

The outcome was that best results were obtained when the scientists chose an aromatic that contained nitrogen. When team members analyzed those lab products, they detected spectral features that matched up well with the distinctive signature that had been extracted from the Titan data by Carrie Anderson, a Cassini participating scientist at Goddard and a co-author on this study.

“This is the closest anyone has come, to our knowledge, to recreating with lab experiments this particular feature seen in the Cassini data,” said Joshua Sebree, the lead author of the study, available online in Icarus. Sebree is a former postdoctoral fellow at Goddard who is now an assistant professor at the University of Northern Iowa in Cedar Falls.
Now that the basic recipe has been demonstrated, future work will concentrate on tweaking the experimental conditions to perfect it. “Titan’s chemical makeup is veritable zoo of complex molecules,” said Scott Edgington, Cassini deputy project scientist at NASA’s Jet Propulsion Laboratory in Pasadena, California. “With the combination of laboratory experiments and Cassini data, we gain an understanding of just how complex and wondrous this Earth-like moon really is.”

**Voyager Map Details Neptune’s Strange Moon Triton**

NASA’s Voyager 2 spacecraft gave humanity its first close-up look at Neptune and its moon Triton in the summer of 1989. Like an old film, Voyager’s historic footage of Triton has been “restored” and used to construct the best-ever global color map of that strange moon. The map, produced by Paul Schenk, a staff scientist at the Lunar and Planetary Institute, has also been used to make a movie recreating that historic Voyager encounter, which took place 25 years ago, on August 25, 1989.

The new Triton map has a resolution of 600 meters (1970 feet) per pixel. The colors have been enhanced to bring out contrast but are a close approximation to Triton’s natural colors. Voyager’s “eyes” saw in colors slightly different from human eyes, and this map was produced using orange, green, and blue filter images.

In 1989, most of the northern hemisphere was in darkness and unseen by Voyager. Because of the speed of Voyager’s visit and the slow rotation of Triton, only one hemisphere was seen clearly at close distance. The rest of the surface was either in darkness or seen as blurry markings. The production of the new Triton map was inspired by anticipation of NASA’s New Horizons encounter with Pluto, coming up a little under a year from now. Among the improvements on the map are updates to the accuracy of feature locations, sharpening of feature details by removing some of the blurring effects of the camera, and improved color processing.

Although Triton is a moon of a planet and Pluto is a dwarf planet, Triton serves as a preview of sorts for the upcoming Pluto encounter. Although both bodies originated in the outer solar system, Triton was captured by Neptune and has undergone a radically different thermal history than Pluto. Tidal heating has likely melted the interior of Triton, producing the volcanos, fractures, and other geological features that Voyager saw on that bitterly cold, icy surface.

Pluto is unlikely to be a copy of Triton, but some of the same types of features may be present. Triton is slightly larger than Pluto, has a very similar internal density and bulk composition, and has the same low-temperature volatiles frozen on its surface. The surface composition of both bodies includes carbon monoxide, carbon dioxide, methane, and nitrogen ices. Voyager also discovered atmospheric plumes on
Triton, making it one of the known active bodies in the outer solar system, along with objects such as Jupiter’s moon Io and Saturn’s moon Enceladus. Scientists will be looking at Pluto next year to see if it will join this list. They will also be looking to see how Pluto and Triton compare and contrast, and how their different histories have shaped the surfaces we see.

Although a fast flyby, New Horizons’ Pluto encounter on July 14, 2015, will not be a replay of Voyager but more of a sequel and a reboot, with a new and more technologically advanced spacecraft and, more importantly, a new cast of characters. Those characters are Pluto and its family of five known moons, all of which will be seen up close for the first time next summer. Triton may not be a perfect preview of coming attractions, but it serves as a prequel to the cosmic blockbuster expected when New Horizons arrives at Pluto next year.

The new Triton map and movie can be viewed at [www.lpi.usra.edu/icy_moons](http://www.lpi.usra.edu/icy_moons).

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**Stardust Discovers Potential Interstellar Space Particles**

Seven rare, microscopic interstellar dust particles that date to the beginnings of the solar system are among the samples collected by scientists who have been studying the payload from NASA’s Stardust spacecraft since its return to Earth in 2006. The seven particles probably came from outside our solar system, perhaps created in a supernova explosion millions of years ago and altered by exposure to the extreme space environment. Supernovas, red giants, and other evolved stars produce interstellar dust and generate heavy elements like carbon, nitrogen, and oxygen necessary for life. The particles would be the first confirmed samples of contemporary interstellar dust.

The research report appeared in the August 15 issue of the journal *Science*. Twelve other papers about the particles appeared the following week in the journal *Meteoritics & Planetary Science*. “These are the most challenging objects we will ever have in the lab for study, and it is a triumph that we have made as much progress in their analysis as we have,” said Michael Zolensky, curator of the Stardust laboratory at NASA’s Johnson Space Center (JSC) in Houston and coauthor of the *Science* paper.
Stardust was launched in 1999 and returned to Earth on January 15, 2006, at the Utah Test and Training Range, 129 kilometers (80 miles) west of Salt Lake City. The Stardust Sample Return Canister was transported to a curatorial facility at JSC where the Stardust collectors remain preserved and protected for scientific study. Inside the canister, a tennis racket-like sample collector tray captured the particles in silica aerogel as the spacecraft flew within ~240 kilometers (149 miles) of a comet in January 2004. An opposite side of the tray holds interstellar dust particles captured by the spacecraft during its seven-year, 4.8-billion-kilometer (3-billion-mile) journey. Scientists caution that additional tests must be done before they can say definitively that these are pieces of debris from interstellar space. But if they are, the particles could help explain the origin and evolution of interstellar dust.

The particles are much more diverse in terms of chemical composition and structure than scientists expected. The smaller particles differ greatly from the larger ones and appear to have varying histories. Many of the larger particles have been described as having a fluffy structure, similar to a snowflake.

Two particles, each only about 2 micrometers (thousandths of a millimeter, or 0.04 inches) in diameter, were isolated after their tracks were discovered by a group of citizen scientists. These volunteers, who call themselves “Dusters,” scanned more than a million images as part of a University of California, Berkeley (UC Berkeley), citizen-science project, which proved critical to finding these needles in a haystack. There two particles, dubbed Orion and Hylabrook, will undergo further tests to determine their oxygen-isotope quantities, which could provide even stronger evidence for their extrasolar origin. Scientists at JSC have scanned half the panels at various depths and turned these scans into movies, which were then posted online, where the Dusters could access the footage to search for particle tracks. A third track, following the direction of the wind during flight, was left by a particle that apparently was moving so fast — more than 15 kilometers (10 miles) per second — that it vaporized. Volunteers identified tracks left by another 29 particles that were determined to have been kicked out of the spacecraft into the collectors.

Four of the particles reported in Science were found in aluminum foils between tiles on the collector tray. Although the foils were not originally planned as dust collection surfaces, an international team led by physicist Rhonda Stroud of the Naval Research Laboratory searched the foils and identified four pits lined with material composed of elements that fit the profile of interstellar dust particles. Three of these four particles, just a few tenths of a micrometer across, contained sulfur compounds, which some astronomers have argued do not occur in interstellar dust. A preliminary examination team plans to continue analysis of the remaining 95% of the foils to possibly find enough particles to understand the variety and origins of interstellar dust.

Once several Dusters tag a likely track, Andrew Westphal, lead author of the Science article, and his team verify the identifications. In the one million frames scanned so far, each a half-millimeter square (0.02 inches), Dusters have found 69 tracks, while Westphal has found two. Thirty-one of these were extracted along with surrounding aerogel by scientists at JSC and shipped to UC Berkeley to be analyzed.

For more information, visit www.nasa.gov/stardust and curator.jsc.nasa.gov/stardust/. 
Meeting Highlights

11th International Planetary Probe Workshop

June 16–20, 2014
Pasadena, California

In June, the 11th International Planetary Probe Workshop (IPPW-11) was held at the California Institute of Technology (Caltech) in Pasadena, California. The workshop brought together engineers, technologists, scientists, mission designers, space agency leaders, and students from around the world for a compelling, week-long opportunity to discuss the exploration of our solar system via in situ missions. This year’s workshop continued the IPPW tradition by encouraging international cooperation in planetary probe missions, new technologies, and scientific discoveries.

On the weekend prior to the workshop, IPPW-11 featured a short course entitled “Discovery and Surprise: Science from Planetary Probes.” The informative course, attended by more than 45 professionals and students, featured lectures from leading international experts on the science gained by sending planetary probes to the various targets in our solar system.

On Monday morning, June 16, the workshop opened with a welcome delivered by the director of the Jet Propulsion Laboratory (JPL), Charles Elachi. Highlights of the morning included an inspiring presentation by Gentry Lee, following his acceptance of the coveted Al Seiff Award. The session also featured keynote addresses by David Miller, NASA’s Chief Technologist, and the European Space Agency’s (ESA) Marcello Coradini.

Throughout the week, professionals and students learned from each other during the eight single-track sessions. These sessions covered technology and science topics, including missions, radio science and science instrumentation, EDL technologies, inflatable and deployable technology, and sustained flight. Sessions on the general subjects of modeling, simulation, and testing, as well as cross-cutting technologies, rounded out the week. On Friday afternoon, June 20, the workshop ended with a summary discussion of the highlights and key issues developed during the week, an explanation of the budget and political realities of NASA’s space missions, recognition of the student authors of winning posters and presentations, and an exciting preview of the plans for IPPW-12.

During IPPW-11, 150 attendees from various NASA centers, JPL, ESA, the Centre National d’études Spatiales (CNES), and the German Aerospace Center (DLR) — as well as European and U.S. universities and aerospace companies — discussed, debated, and learned from nearly 70 presentations and 60 posters on display during the workshop. In addition, European and U.S. students, many of whom were on scholarship, were given the opportunity to dialogue with aerospace professionals.

In keeping with IPPW’s goals of enhancing communications to foster collaborations, IPPW-11 offered tours of JPL and the California Science Center, including an up-close look at NASA’s Space Shuttle Endeavor. The week began with an opening reception. Among other opportunities for social interaction were a quick tour of the Griffith Observatory, a gala banquet featuring a spectacular view of Los Angeles and environs, and an evening walking tour of downtown Los Angeles.
Eighth International Conference on Mars

July 14–18, 2014
Pasadena, California

This past July, more than 650 “martians” from 21 countries gathered at the California Institute of Technology (Caltech) to discuss the status of our exploration of the Red Planet, from the perspective of geoscientists, atmospheric scientists, astrobiologists, and engineers. Since the Seventh Mars conference held in 2007, seven Mars missions have been returning data [Mars Odyssey, Mars Exploration Rovers (Spirit/Opportunity), Mars Express, Mars Reconnaissance Orbiter, Phoenix, and Mars Science Laboratory (Curiosity)]. Additionally, telescopic observations, studies of martian meteorites, laboratory work, and modeling studies have progressed our understanding of Mars’ history and environment.

Attendees of the conference presented the latest discoveries, discussed their studies’ implications for understanding Mars, and refocused the primary scientific questions by identifying new paradigms and the most important unknowns.

Convened by David Beaty [Jet Propulsion Laboratory (JPL)], Bethany Ehlmann (Caltech), Daniel McCleese (JPL), Michael Meyer (NASA), and Richard Zurek (JPL), with funding provided by NASA and assistance by the Lunar and Planetary Institute, the conference received 499 abstract submissions. Of these, about a third had female first authors, about a fifth had first authors at a non-U.S. institution, and about a third had student or postdoc first authors — reflective of the broad and diverse conference attendance.

Abstracts were organized into big-picture, thematic sessions in a single-track of oral presentations that started with invited presentations aimed to provide the broad audience with proper context for the session’s contents. This, along with the late afternoon sessions of ~100 posters per day, aimed to generate cross-disciplinary discussion. This goal was emphasized in the concluding conference session, which consisted of a synthesis discussion involving the community and a panel of “Integrators” representing each broad discipline in Mars studies (Geology, Phil Christensen; Climate, Rich Zurek; Life, Dave Des Marais; and Preparation for Human Exploration, Marcello Coradini), supported by teams of graduate students and postdocs, and moderated by Lisa Pratt.

The emergence of Mars system science was apparent:

- Two key cross-disciplinary discoveries that were referenced again and again in conference presentations — mineral distribution and diversity, and large-magnitude cyclic obliquity-driven climate variations — have profound implications for understanding the martian geologic record, climate, and habitability.
Meeting Highlights continued . . .

- The evidence for geographically widespread liquid water on past Mars is now unambiguous (and inquiries continue into possible ephemeral water in the present day). This evidence, along with the detection of key elements and energy sources, indicates that early Mars was habitable — but did life develop? Important unknowns are liquid water’s persistence and the environmental setting implicated by the mineral and chemical record.

- New means of getting at time (timing, duration) estimates of specific environmental conditions and petrology are required to understand the rock record. An oft-asked question to geologists from climate scientists dealing with a less luminous young Sun was “Did it have to rain?,” and so the debate continues between a cold early Mars with snow, ice caps, and transient water versus a warm early Mars with an integrated hydrologic system and standing bodies of water.

- Mars today has active processes involving dust, water, and atmospheric gases, which together with geological and chemical evidence (e.g., minerals and isotopes) are providing windows into the past, while challenging the physical processes and scales currently resolvable in Mars climate models. Understanding modern Mars is also important for preparing for future in situ resource utilization by human exploration.

Key presentations from this conference, in addition to abstracts and many ePosters, have been posted on the main conference website (www.hou.usra.edu/meetings/8thmars2014) to serve as resources to all people interested in the current state of our understanding of Mars, including researchers and students unable to attend the conference, and people preparing lectures about Mars science. Included are the summary talks given by the invited speakers of each conference session and the synthesis presentations that formed the basis of the discussion during the conference’s final session. Presented overviews of the missions that just arrived at Mars (NASA’s MAVEN and ISRO’s Mars Orbiter Mission) and missions actively under development for launch during the period 2016–2020 (ESA’s 2016 and 2018 ExoMars; NASA’s 2016 InSight lander and 2020 Mars Rover) are also available.
Resources for Researchers

Atlas of Lunar Sinuous Rilles

The LPI-JSC Center for Lunar Science and Exploration [a member of NASA’s Solar System Exploration Research Virtual Institute (SSERVI)] and a collaborating SSERVI team at Brown University have generated an online “Atlas of Lunar Sinuous Rilles.” The new atlas can be found at www.lpi.usra.edu/lunar/rilles.


This new resource is designed to support both the science and exploration communities and their integrated mission activities. It is also a useful training and educational tool for the planetary science community.

For a complete list of LPI lunar atlases, visit www.lpi.usra.edu/lunar/lunar_images. For a complete list of maps and databases from the Brown University Planetary Geosciences Group, visit www.planetary.brown.edu/html_pages/data.htm.

New LADEE Data Available

The NASA Planetary Data System announces the release of certified Neutral Mass Spectrometer (NMS) and Ultraviolet Visible Spectrometer (UVS) observations from the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, covering data from both the primary and extended missions. To access the data, visit the PDS Atmospheric Discipline Node website at atmos.nmsu.edu or go directly to pds-atmospheres.nmsu.edu/data_and_services/atmospheres_data/LADEE/mainr.html.

New LROC Website Now Live

The Lunar Reconnaissance Orbiter Camera (LROC) Team has announced the release of its new and improved website.

LROC is a system of three cameras mounted on the Lunar Reconnaissance Orbiter (LRO) that capture high-resolution photos of the lunar surface. Using the redesigned website, it is now even easier to view featured images and share the wonder using popular social media tools, use intuitive Lunaserv and
Resources for Researchers continued . . .

Quickmap interfaces to conveniently locate the data needed for research, explore spectacular data products like the North Polar Mosaic, find reduced data records like NAC Digital Terrain Models (DTMs), and request targeted observations.

The LROC Team updates featured images frequently, and the website is fully RSS enabled, making it easy to discover when new images and other website updates have been released.

Visit the new and improved LROC website at lroc.sese.asu.edu.

LPI Introduces New Mars Topical Websites

In response to the growing interest in the conditions that prevailed on Mars during its first billion years of geologic history and their implications for the development of life, LPI has created the Early Mars topical website (www.lpi.usra.edu/early_mars), the purpose of which is to provide one-stop access to news and information about the latest in Early Mars research, past and future meetings, special issues, educational resources and student research opportunities, a searchable database of Early Mars peer-reviewed publications, and a variety of other web-based resources. A second Mars topical website, Mars Polar Science and Exploration (www.lpi.usra.edu/mars_polar), is also available.

These websites are intended as an evolving and regularly updated community resource. Contributions of research news, citations of peer-reviewed publications for inclusion in the Early Mars or Mars Polar Science Reference Libraries, photos from past meetings and field trips, and other relevant content are welcome. Contributed material or feedback regarding potential changes or additions to these websites can be sent to clifford@lpi.usra.edu, with “Early Mars” or “Mars Polar Science” in the subject line.
“Spotlight on Education” highlights events and programs that provide opportunities for planetary scientists to become involved in education and public outreach and to engage science educators and the community. If you know of space science educational programs or events that should be included, please contact the Lunar and Planetary Institute’s Education Department at shupla@lpi.usra.edu.

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration, solar system formation and evolution, and Mars exploration. Resources for evening observing session events include the Night Sky Network’s Discover the Universe Guides at nightsky.jpl.nasa.gov/news-display.cfm?News_ID=611. Consider getting in touch with local astronomical societies, planetariums and museums, local scientists, and NASA’s Solar System Ambassadors (www2.jpl.nasa.gov/ambassador/directory.htm) — ask them to join your events and share their experiences or resources with the children.

Comet Siding Spring Encounters Mars —

On October 19, Comet Siding Spring had a close encounter with the Red Planet (see the cover story of this issue). The comet did not collide with Mars, but some of the comet dust was expected to impact and make a meteorite shower. NASA missions made preparations to observe the event; as seen from Mars, the comet was expected to fill a good portion of the sky. For more details, see mars.nasa.gov/comets/sidingspring.

Rosetta Lands on Comet Churyumov-Gerasimenko —

The Rosetta Mission arrived at its target on August 6. In November, its lander Philae will attempt the first soft touchdown in history on a comet (see cover story of this issue). Over an entire Earth year, as it approaches the Sun, Rosetta will orbit the comet, mapping its surface and studying changes in its activity. Information about Rosetta is available at rosetta.jpl.nasa.gov/.

Geminid Meteor Shower —

This popular meteor shower, one of the best and most reliable each year, peaks during the evening into the early morning hours of December 13–14. This year observers will want to observe before the third quarter Moon rises (around midnight). More information is available at solarsystem.nasa.gov/planets/geminids.cfm.
Dawn Arrives at Ceres —

The Dawn mission left the asteroid Vesta in 2012 and is on its way to dwarf planet Ceres, the largest asteroid. It is expected to arrive in March 2015. A variety of educational materials for hosting an “i Ceres” event are available at dawn.jpl.nasa.gov/education/.

New Horizons Reaches Pluto —

The New Horizons mission will fly past this mysterious icy dwarf planet on July 14, 2015. Information and resources for your Pluto celebrations are available at pluto.jhuapl.edu/education/index.php.

NASA Postdoctoral Program Fellowships

The NASA Postdoctoral Program (NPP) supports NASA’s goal to expand scientific understanding of Earth and the universe in which we live. Selected by a competitive peer-review process, NPP fellows complete one- to three-year fellowships that offer scientists and engineers unique opportunities to conduct research in fields of science relevant to NASA. These opportunities advance NASA’s missions in Earth science, heliophysics, planetary science, astrophysics, space bioscience, aeronautics and engineering, human exploration and space operations, and astrobiology. Opportunities are available at NASA centers and other NASA-approved sites.

Interested applicants may apply by one of three annual application deadlines: March 1, July 1, and November 1. For more information and application procedures, go to nasa.orau.org/postdoc. Questions about this opportunity should be directed to nasapostdoc@orau.org.
NASA SMD Scientist Speaker’s Bureau Taking Requests

The new NASA Science Mission Directorate’s Scientist Speaker’s Bureau is now live! Educators can search for speakers by topic, and participating scientists can limit their availability by which audiences and audience size they are most comfortable addressing, as well as whether they are willing to travel and to give presentations via the Internet. No funding will be provided by the Speaker’s Bureau for travel; if funding is needed, the institution and scientist should discuss it in advance.

- Educators are welcome to examine the site and place their requests through www.lpi.usra.edu/education/speaker/request.
- SMD scientists are encouraged to enter their information into the database, at www.lpi.usra.edu/education/speaker/.
- For further information, please contact planetaryforum@lpi.usra.edu.

CAPER Workshops for College Faculty

In the next six months, the Center for Astronomy and Physics Education Research (CAPER), NASA, the National Science Foundation (NSF), the National Society of Black Physicists (NSBP), and a collection of collaborators will be hosting six teaching workshops for college faculty. All the workshops are focused on astronomy and the space sciences, and one is specifically designed for faculty who work with pre-service teachers. Full information and registration for the workshops can be found on the CAPER website at www.caperteam.com/currentworkshops.

New Impact Cratering Education Site

A new series of video simulations of impact cratering processes has been developed for similar classroom use. “Video Simulations of Impact Cratering Processes” explore how impactor size and velocity, as well as target gravity and temperature, affect the sizes and morphologies of impact craters. The videos can be run in real time from the website or, if users prefer, downloaded to their own computers. Comparisons between the craters produced in the simulations and actual craters on the Moon and Earth are provided.
with links to additional data associated with those structures. To access the videos, visit www.lpi.usra.edu/exploration/training/resources/impact_cratering.

2015 RASC-AL Aerospace Concepts Design Competition

NASA and the National Institute of Aerospace announce the 2015 Revolutionary Aerospace Systems Concepts-Academic Linkage (RASC-AL) Aerospace Concepts competition. RASC-AL is a design project competition for university-level engineering students and faculty.

The 2015 RASC-AL contest challenges participants to design projects based on real NASA problems, responding to one of four themes: Earth-Independent Mars Pioneering Architecture; Earth-Independent Lunar Pioneering Architecture; Mars’ Moons Prospector Mission; and Large-Scale Mars Entry, Descent, and Landing Pathfinder Mission.

Concepts derived from the design projects could potentially be implemented by NASA. Interested teams are encouraged to submit a notice of intent by November 3, 2014, and teams must submit an abstract for their proposed project by January 11, 2015. For more information about this competition, visit nianet.org/RASCAL.

NASA Wavelength: Online Science Education Resource

This online science resource is designed for educators and students to help bring Earth, the solar system, and the universe into their schools and homes. The site features thousands of reviewed resources organized by topic and audience level from elementary to college, and out-of-school programs that span the extent of NASA science. Educators can locate educational resources through information on educational standards, subjects, keywords, or other relevant details, such as learning time required to carry out a lesson or an activity, cost of materials, and more. Users can receive e-mail updates on new content, and share the latest information through social media and e-mail. Check it out at nasawavelength.org.
Planetary Science E/PO Resources Sampler and Quick Start Guide

Looking for education resources connected to planetary missions and themes? The NASA SMD Education and Public Outreach Planetary Forum has a brochure that connects the big questions and themes to existing programs and resources, along with suggestions on how to use the resources. Find it at smdepo.org/data/uploads/PS_EPO_Resources_2.pdf.
Donald A. Beattie, 1929–2014

Donald A. Beattie passed away on August 22, 2014, at the age of 85. Born October 30, 1929, in Staten Island, New York, Beattie was a retired U.S. Navy carrier pilot, but was perhaps best known for having managed the Apollo program’s lunar surface experiments for NASA. In this capacity he assisted in training the astronauts to perform geology on the Moon. He was also a pioneer in alternative energy and in this capacity worked on nuclear, wind, and geothermal energy systems.

After graduating from Columbia College and receiving a commission in the U.S. Navy, Beattie began his first career as a carrier pilot, serving in active duty from 1951 to 1956 and in Ready Reserve squadrons until 1967. Upon leaving the Navy, he returned to graduate school at the Colorado School of Mines, receiving a M.S. degree in 1958 with majors in Geological Engineering and Geophysics. Hired by Mobil Oil after graduate school, he began a second career supervising a geology field party mapping the large Mobil concessions in little-known jungle and rain forest regions of Colombia, South America.

While working in Colombia, he learned that NASA was recruiting geologists to help plan Apollo lunar exploration. He was hired for a job at NASA Headquarters and began work in September 1963 in the newly formed Advanced Manned Missions Office. In this position he participated in planning for Apollo and post-Apollo missions. From 1965 to 1973, he managed NASA offices that had responsibility for the development of experiments, training, and simulations for these missions, and eventually became NASA Headquarters Program Manager, Lunar Surface Experiments.

At the end of the Apollo program, he transferred to the National Science Foundation (NSF) and was appointed Director of the Advanced Energy Research and Technology Division. In 1975, the Energy Research and Development Administration (ERDA) was formed by President Gerald Ford, and Beattie was appointed as Deputy Assistant Administrator (later as Assistant Administrator) for Solar, Geothermal, and Advanced Energy Systems. In 1978, after President Jimmy Carter further consolidated federal energy programs by establishing the cabinet level Department of Energy (DOE), Beattie was appointed Assistant Secretary (acting) for Conservation and Solar Applications, reporting to DOE Secretary James Schlesinger.

Beattie returned to NASA in August 1978 as Division Director, Energy Systems Division. This office was responsible for managing all the energy RD&D programs underway at Lewis Research Center, Marshall Space Flight Center, Johnson Space Center, Langley Research Center, and the Jet Propulsion Laboratory. Advanced technology projects were built and demonstrated for solar and wind energy, electric and hybrid vehicles, magnetohydrodynamics, and fuel cells.

Leaving NASA in 1983, Beattie joined BDM International, an engineering services company, as Vice President of Houston Operations, and in 1984 he started his own consulting business. Among his clients were many Fortune 500 companies such as General Electric, Boeing, Raytheon, Martin Marietta, Lockheed Martin, Chevron, and North American Rockwell.
Beattie was the author of dozens of articles published in scientific journals, as well as the books *History and Overview of Solar Heat Technologies*, *Taking Science to the Moon*, *ISScapades: The Crippling of America’s Space Program*, and his autobiography, *No Stone Unturned*.

— Text courtesy of Robert Godwin, Apogee Books

**Noel W. Hinners, 1925–2014**

Noel W. Hinners, a geologist and soil chemist who helped NASA launch some of its farthest-reaching scientific probes into space — to retrieve Moon rocks, map the surface of Mars, and peer beyond intergalactic dust to where stars are born — died on September 5 in Littleton, Colorado. He was 78.

Hinners, who held various titles as an administrator and chief scientist for NASA in the 1970s and 1980s, was the main advocate for pure scientific research in an organization ruled by rocket engineers and pilots. He began his space career in 1963 by helping plan lunar exploration, and was only 33 years old when Apollo 11 landed on the Moon. After the first manned lunar landing, Hinners chaired the committee that decided where later manned lunar missions would touch down, convincing others that the more extreme the terrain and the more layers of rock exposed, the more geological information the site would reveal. With geological field training provided by Hinners and his colleagues, Apollo astronauts from 1969 to 1972 brought back about 850 pounds of lunar rock from valleys, crater beds, and ravines that NASA had previously considered too risky to venture into.

He worked on the Apollo program until 1972, when he became the space agency’s director of lunar programs. Hinners not only helped plan the final Apollo missions, but also oversaw the design of scientific projects for almost every NASA venture for the next seven years, including the Skylab space station; the first unmanned missions to Saturn, Mars, and Venus; and the planning stages for the space shuttle and the Hubble orbiting telescope.

Hinners often represented NASA at congressional budget hearings. His self-deprecating humor made him well suited to the role, said Alex Roland, a Duke University professor who has studied the history of NASA. “He was very good at making the case for space science without pouting or stamping his foot,” said Roland. But he added that Hinners’ patience had been frayed by relentless federal budget cuts in the 1970s and 1980s.

Hinners told interviewers that he was equally frustrated by NASA’s efforts to design missions with an eye toward popular support — the “strategy of firsts,” as he called it: the first comet flyby, the first pictures from the atmosphere of Jupiter, the first images from Venus. “We are the victim of our own success at firsts, and there aren’t many left to be done,” he said in an interview with *Science* magazine in 1979. Meanwhile, he said, there were Moon rocks collected 10 years earlier that had still not been studied for lack of research money from Congress.
Hinners later served as the director of the National Air and Space Museum in Washington and the director of the Goddard Space Flight Center. He retired from NASA as its third-ranking executive in 1989, leaving to become an executive with Lockheed, where he served as vice president of flight systems, whose responsibilities included NASA’s Mars Surveyor Program and Stardust, the first program dedicated to exploring a comet.


Gerhard Neukum, 1944–2014

Gerhard Neukum, former Professor of Planetary Sciences at the Freie Universität in Berlin, Germany, passed away on September 21. He was one of the most prominent planetary researchers in Germany and one of the world’s recognized experts in the chronology of solar system bodies.

Born February 23, 1944, in Johnsdorf, Germany, Neukum originally studied physics at the University of Heidelberg, but later changed to the study of geosciences. Neukum was drawn to the cosmos in the 1970s when, as a student at the University of Heidelberg, he landed a plum spot conducting research for NASA’s Apollo lunar program. He was enchanted as he contemplated photos of the Moon, but he was also frustrated. “I didn’t just want to analyze data but send my own camera up there, one that would produce better data than all previous cameras,” he says. He eventually invented just such a thing, a stereoscopic imager that earned a spot onboard a 1996 Russian Mars probe. But that probe fell a wee bit short of Mars, crashing into the Pacific Ocean after orbiting Earth twice. “On the plane back to Moscow,” Neukum recalls, “I thought to myself, ‘This can’t be the end.’”

It wasn’t. In 2003 the European Space Agency launched its Mars Express spacecraft with the next iteration of Neukum’s camera on board. The ship reached its target, and before long, Neukum’s 3-D color images were being admired around the world. The camera’s nine sensors simultaneously scan an object, each from a different perspective, then combine those images with pictures taken by a telephoto lens. The images that result are 100 times as sharp as those from the Viking Mars missions of the 1970s.

Neukum’s unique combination of skills led to his participation in a range of space science projects, eventually serving as Director of the DLR Institute of Planetary Exploration, Berlin, then the Professor of Planetary Sciences at the University of Berlin. In addition to being the pioneer behind the High-Resolution Stereo Camera (HRSC) on Mars Express, Neukum was also a member of the imaging team on the NASA/ESA Cassini/Huygens mission, as well as a Co-Investigator for both the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) Experiment and the Rosetta Lander Imaging System (ROLIS) on ESA’s Rosetta mission.
Frederick I. Ordway III, 1927–2014

Frederick Ira Ordway III, American space scientist and author of visionary books on spaceflight, passed away on July 1, 2014. He was 87 years old.

Ordway was born in New York City and grew up in Maine. He studied geosciences at Harvard University and later studied abroad at the Sorbonne and other European institutions. After working in mining for a while, he got involved in space, working for Reaction Motors, Inc. (RMI), of New Jersey, where he worked on a liquid propellant rocket. After his rocketry work, Ordway joined Republic Aviation, Inc., in New York. One day in New York City, when meeting with his friend Arthur C. Clarke, Ordway was introduced to film director Stanley Kubrick, who then invited Ordway to serve as technical advisor on his new film, 2001: A Space Odyssey.

After spending three years working on that breakthrough film project, Ordway became a professor at the University of Alabama in Huntsville, and later served as a special assistant to Dr. Robert Seamans, who was the first director of the agency that eventually became the Department of Energy (DOE).

Ordway was very active in studying and preserving space history, writing a number of books and more than 350 articles about space travel. At the time of his death he was the longest-serving member of the American Rocket Society, which he joined in 1939. He was awarded an honorary doctorate by the University of Alabama Huntsville 1992. Ordway also served on the National Space Society Board of Directors and Board of Governors, and was awarded the 2012 National Space Society Space Pioneer Award for a Lifetime of Service to the Space Community. In October 2013 he was presented with the Arthur C. Clarke Award for Lifetime Achievement.
Sean Solomon to Receive National Medal of Science

Sean Solomon, former principal investigator for the NASA Astrobiology Institute team at the Carnegie Institution in Washington, DC, has been selected to receive the National Medal of Science. Solomon is now the Director of Columbia University’s Lamont-Doherty Earth Observatory, and serves as principal investigator for NASA’s MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission. MESSENGER is the first spacecraft to orbit Mercury and is currently completing a second extended mission at the solar system’s innermost planet. Additional NASA missions in which Solomon has been involved include the Magellan mission to Venus, the Mars Global Surveyor mission, and the GRAIL mission to the Moon.

The National Medal of Science was created in 1959 and is the highest scientific honor in the United States. Recipients are selected by the President of the United States from a pool of nominees based on their outstanding contributions to science and engineering.

Pieters Awarded Medal of International Cooperation

Carle Pieters, professor in the Department of Earth, Environmental and Planetary Sciences at Brown University, has been awarded the Medal of International Cooperation by the Committee on Space Research (COSPAR), an organization that promotes international research in space. Pieters received the medal at the biennial COSPAR Scientific Assembly in Moscow, Russia. The medal is awarded every two years to “a scientist who has made distinguished contributions to space science and whose work has contributed significantly to the promotion of international scientific cooperation.” Pieters has been a member of the Brown faculty since 1980. She is a principal investigator for NASA’s Moon Mineralogy Mapper, which flew onboard India’s Chandryaan-1 spacecraft in 2008. She is also a co-investigator on NASA’s Dawn mission exploring the asteroids Ceres and Vesta. During her career, she has assisted in planning international space exploration with Germany, England, Japan, Russia, and India. COSPAR is part of the International Council on Science, a nongovernmental organization with a mission to strengthen international scientific research.

Former Lunar Exploration Interns Receive COSPAR Award

A paper written by a team of former Lunar Exploration Interns was selected for the prestigious COSPAR Outstanding Paper Award for Young Scientists. The award was presented during the 40th COSPAR Scientific Assembly, which was held in Moscow in August.
The paper, “Identification and Characterization and Science-Rich Landing Sites for Lunar Lander Missions Using Integrated Remote Sensing Observations,” was co-authored by a group of students who spent the summer of 2010 at the Lunar and Planetary Institute (LPI) in Houston as part of the Lunar Exploration Summer Intern Program.

The lead author of the article is former intern Jessica Flahaut (Laboratoire de Géologie de Lyon); co-authors include former interns Jean-François Blanchette-Guertin (University of British Columbia), Christine Jilly (University of Hawai‘i at Manoa), Priyanka Sharma (University of Arizona), and Audrey Souchon (Université de Toulouse III), along with advisor David Kring (LPI).

The COSPAR Publications Committee, relying on assistance and advice from Associate Editors and Commission/Panel officers, recommend recipients for the award to the Bureau. Candidates must be first authors under 31 years of age at the time the manuscript is submitted for publication in Advances in Space Research, and award recipients are selected from among a minimum of five competitors per Commission/Panel.

Nininger Meteorite Award Recipients Announced

The ASU Center for Meteorite Studies is pleased to announce that Ingrid Daubar, a graduate student at The University of Arizona, is the recipient of the 2013 Nininger Meteorite Award, and Emily Pringle, a graduate student at Washington University in St. Louis, received an Honorable Mention for the award. The Nininger Meteorite Award recognizes outstanding student achievement in the meteoritical sciences as embodied by an original research paper, and each nomination is reviewed by a panel of experts from a broad array of fields in meteoritical science.

Daubar’s paper, “The Current Martian Cratering Rate,” reports on the discovery of 248 dated impact sites known to have formed on Mars within the last few decades. Before and after images constrain the creation dates of these small, meter- to decameter-sized craters. A subset of the new impacts was scaled to the area searched, as well as the time over which it was searched, to minimize observational biases. Daubar and her coauthors used this new technique to measure the current martian impact rate, finding that more than 200 new craters larger than ~4 meters in diameter are forming on Mars each year.

Solid bodies in the solar system are dated using cratering chronology models: The number of craters of different sizes gives an estimate of how long that surface has been bombarded. These models are based on crater counts done on the Moon, and calibrated with known radiometric ages of returned Apollo samples. To apply these models to other bodies such as Mars, a number of approximations and assumptions must be made. The measurement Daubar and coauthors made of the current cratering rate on Mars allowed these models to be assessed. In fact, the
measured rate is significantly lower than those predicted by the models, by a factor of three to five. This brings into question whether the ages resulting from these widely used models are accurate when applied to craters this small.

Daubar’s research was performed under the advisement of Dr. Alfred McEwen.

Pringle’s paper, “Redox State During Core Formation on Asteroid 4-Vesta,” presented research that coupled high-precision measurements of silicon isotopic ratios in achondrites with models of Si behavior during metal-silicate differentiation, to aid in understanding planetary core formation.

The primary differentiation of the terrestrial planets involved the separation of iron-rich metal from silicate to form a core and mantle, and their chemical and isotopic compositions are closely linked to the conditions (e.g., temperature, pressure, oxidation state) prevailing during core formation. As Si isotopes can be fractionated between metal and silicate under these conditions, they are particularly useful indicators of core formation processes.

The Si isotope compositions of howardite-eucrite-diogenite (HED) meteorites, which represent samples from the silicate portion the asteroid 4-Vesta, are slightly offset from chondritic values, consistent with the core of 4-Vesta containing 1–2 wt.% Si. Furthermore, since the amount of Si in the metal phase is dependent on temperature, pressure, and oxygen fugacity, it is possible to use the calculated amount of Si in 4-Vesta’s core to probe the conditions during core formation. This represents a novel application of the Si isotope system to study core formation in differentiated planetary bodies.

Pringle’s research was performed under the advisement of Dr Frederic Moynier.

**USRA Announces New President and CEO**

The Universities Space Research Association (USRA) announced that Dr. Jeffrey A. Isaacson joined USRA as President and CEO, effective October 20, 2014. USRA is a national, nonprofit consortium of universities chartered in 1969 by the National Academy of Sciences at the request of NASA. USRA operates programs and institutes, including the Lunar and Planetary Institute, focused on research and education in most of the disciplines engaged in space-related science and engineering. Institutional membership in USRA now stands at 105 leading research universities.

Isaacson has a distinguished career spanning both industry and the nonprofit sector, and a depth of experience in engaging academia and the broader scientific and technology communities in support of achieving national objectives. Isaacson was selected following an extensive national search, undertaken by the USRA Board of Trustees, assisted by the executive search firm of Korn Ferry. Prior to joining USRA, Isaacson served as Vice President for Defense Systems and Assessments at Sandia National Laboratories, where he was responsible for development and integration of advanced science and technology into state-of-the art systems for the National Nuclear Security Administration,
the Department of Defense, and other national security agencies. Before joining Sandia in 2011, he was at RAND Corporation, where he was Vice President and Director of the Arroyo Center, the U.S. Army’s federally funded research and development center (FFRDC) for studies and analysis. He had returned to RAND in 2007 from Lockheed Martin Space Systems Company, where he directed systems engineering and integration of the Space Based Infrared System-High. This multibillion-dollar satellite program provides the U.S. with a next-generation capability for missile warning. Prior to joining Lockheed Martin in 2004, Isaacson served in a variety of research and management positions for nearly 13 years at RAND, including Vice President and Director of the National Defense Research Institute, the FFRDC supporting the Office of the Secretary of Defense, the Joint Staff, and the defense agencies. As a Department of Energy graduate fellow in the 1980s, he conducted research at the Princeton Plasma Physics Laboratory and the Lawrence Livermore National Laboratory.

Isaacson is a member of the Army Science Board and the M.I.T. Corporation Visiting Committee for the Engineering Systems Division. He earned degrees at Columbia University, Princeton University, and the Massachusetts Institute of Technology, where he received his Ph.D. in theoretical physics. Isaacson is also a veteran of Operation Enduring Freedom, having served in Afghanistan as a mobilized reservist from May 2009 to April 2010.

“I am proud and excited to be joining USRA,” said Isaacson. “USRA is an impressive organization, with a 45-year history of conducting important work with NASA and, more recently, for the National Science Foundation and other government sponsors. I am looking forward to working alongside its dedicated employees, supporting its government sponsors, and serving its member institutions.”

**NASA Selects New Science Teams for Astrobiology Research**

NASA has awarded five-year grants totaling almost $50 million to seven research teams nationwide to study the origins, evolution, distribution, and future of life in the universe.

“With the Curiosity rover characterizing the potential habitability of Mars, the Kepler mission discovering new planets outside our solar system, and Mars 2020 on the horizon, these research teams will provide the critical interdisciplinary expertise to help interpret data from these missions and future astrobiology-focused missions,” said Jim Green, director, Planetary Science Division, at NASA Headquarters, Washington.

Average funding for each team will be approximately $8 million. The interdisciplinary teams will become members of the NASA Astrobiology Institute (NAI), headquartered at NASA’s Ames Research Center, Moffett Field, California.
Milestones continued . . .

The selected teams are:

- NASA’s Goddard Space Flight Center, Greenbelt, Maryland. Team lead is Michael Mumma. Research will investigate one theorized source of Earth’s water and the organic molecules needed for life: comets and the other small bodies in our solar system. The results of this research will inform the search for habitable environments in our solar system and habitable planets around other stars.

- NASA’s Ames Research Center, Moffett Field, California. Team lead is Scott Sandford. Research will address the chemistry that occurred to create the organic molecules that may have been brought to the early Earth by comets and other small bodies.

- NASA’s Jet Propulsion Laboratory, Pasadena, California. Team lead is Isik Kanik. Research will conduct laboratory experiments and field research in environments on Earth, such as The Cedars in Northern California, to understand the habitability of extraterrestrial icy worlds such as Europa, Ganymede, and Enceladus.

- The Search for Extraterrestrial Intelligence (SETI), Mountain View, California. Team lead is Nathalie Cabrol. Research will produce guiding principles to better understand where to search for life, what to search for, and how to recognize finding evidence of past or current life. The goal of the proposed research is to best prepare for NASA’s Mars 2020 rover.

- The University of Colorado in Boulder. Team lead is Alexis Templeton. Research will study what scientists call “Rock-Powered Life.” Rocky planets store enormous amounts of chemical energy that, when released through the interaction of rocks with water, can power living systems on Earth, as well as on other planets such as Mars.

- University of California, Riverside. Team lead is Timothy Lyons. Research will examine the history of oxygen in Earth’s atmosphere and ocean between 3.2 and 0.7 billion years ago. This is a time range in which the amount of oxygen present is thought to have increased from almost nothing to the amounts present today. This work will address the question of how Earth has remained persistently inhabited through most of its dynamic history and would provide NASA exploration scientists a template to investigate the presence of habitable conditions on Mars and other planetary bodies.

- University of Montana in Missoula. Team lead is Frank Rosenzweig. Research will look to unlock the secrets of life’s transitions from small “units” conducting simple chemical reactions to self-organizing, self-reproducing, energy-gathering systems that range in complexity from single cells to ecosystems.

“The intellectual scope of astrobiology is vast, from understanding how our planet went from lifeless to living, to understanding how life has adapted to Earth’s harshest environments, to exploring other worlds with the most advanced technologies to search for signs of life,” said Mary Voytek, director, astrobiology program, NASA Headquarters. “The new teams cover that breadth of astrobiology, and by coming together in the NAI, they will make the connections between disciplines and organizations that stimulate fundamental scientific advances.”
NASA Lunar Mission Wins 2014 Popular Mechanics Breakthrough Award

NASA’s Lunar Atmosphere and Dust Environment Explorer (LADEE) mission has received the Popular Mechanics 2014 Breakthrough Award for innovation in science and technology. The 10th annual Breakthrough Awards recognize innovators, engineers, and scientists responsible for changing our world. The award acknowledges LADEE’s modular flexible construction and laser data transfer capability, which can send and receive data more than six times faster than the quickest space-based radio signals.

“We’re proud of the LADEE mission’s accomplishments and this recognition,” said S. Pete Worden, director of NASA’s Ames Research Center in Moffett Field, California, which designed, developed, built, integrated, tested and controlled the spacecraft. “LADEE may have been the first Ames-built spacecraft, but after the Kepler mission’s win in 2009 and the Lunar Crater Observation and Sensing Satellite (LCROSS) mission’s win in 2010, it’s the third Ames mission to be honored with this award.”

LADEE launched in September 2013, from the Mid-Atlantic Regional Spaceport at NASA’s Wallops Flight Facility on Wallops Island, Virginia. The car-sized lunar orbiter gathered detailed information on the structure and composition of our Moon’s thin atmosphere and data to determine whether dust is being lofted into the lunar sky. A thorough understanding of these characteristics of our nearest celestial neighbor will help researchers understand other bodies in the solar system, such as large asteroids, Mercury, and the moons of outer planets.

The first Ames-built spacecraft enjoyed many other firsts throughout its mission. The occasion of its launch was the first flight of a converted U.S. Air Force Minotaur V rocket, an excess ballistic missile converted into a space launch vehicle and operated by Orbital Sciences Corporation of Dulles, Virginia. It also was the first launch beyond Earth orbit from the agency’s Virginia launch facility.

Hosted onboard LADEE for its ride to lunar orbit was the Lunar Laser Communication Demonstration (LLCD) terminal. From a distance of almost a quarter-of-a-million miles, LLCD demonstrated record-breaking upload and download speeds. The cooperative mission with a team from NASA’s Goddard Space Flight Center and MIT’s Lincoln Laboratory revealed the possibility of expanding broadband capabilities in future space communications development.

LADEE was built using an Ames-developed Modular Common Spacecraft Bus architecture — a general purpose spacecraft design that allows NASA to develop, assemble, and test multiple spacecraft modules at the same time. The LADEE bus structure was a lightweight carbon composite weighing 547.2 pounds unfueled and 844.4 pounds when fully fueled.

The successful mission was concluded April 18 when ground controllers at Ames confirmed the spacecraft impacted the surface of the Moon, as planned. LADEE was designed for a relatively short mission, as the science goals only required 100 days of data collection.
“From beginning to end, LADEE was a testament of unparalleled teamwork and unique innovation,” said Joan Salute, LADEE program executive at NASA Headquarters in Washington. “The mission established a new technology paradigm, opening a new chapter for spacecraft design and construction.”

**NASA Announces Early Career Faculty Space Tech Research Grants**

NASA has selected seven university-led proposals for the study of innovative, early stage technologies that address high priority needs for America’s space program. The selected proposals for unique, disruptive, or transformational space technologies will address challenges in robotic mobility when traversing extreme terrain, in developing lightweight and multifunctional materials and structures, and in lowering the size, weight, and power of lasers for space missions. The selected technology research areas require dramatic improvements over existing capabilities for future science and human exploration missions.

“Technology drives exploration, and these researchers will provide fuel for NASA’s innovation engine,” said Michael Gazarik, NASA’s associate administrator for the Space Technology Mission Directorate in Washington. “Sustained investments must be made to mature the capabilities required to reach the challenging destinations that await exploration, such as an asteroid, Mars, and outer planets. These investments help to assure a robust university research community dedicated to advanced space technology development.”

The grants from NASA’s Space Technology Research Grants Program are worth approximately $200,000 per year with up to three years of research possible. The grants are awarded to outstanding faculty researchers early in their careers as they conduct space technology development of high priority to NASA.

The selected NASA Early Career Faculty researchers are:

- Aaron Dollar, Yale University, New Haven, Connecticut; “Digital Manufacturing of Lightweight and Efficient Structures via Reconfigurable Lattice Printing”
- Christopher Hansen, University of Massachusetts, Lowell; “Design and Fabrication of Aerospace-Grade Digital Composite Materials”
- Marc Killpack, Brigham Young University, Provo, Utah; “Model Predictive Control of an Underdamped, Pneumatically Actuated, Soft Robot with Flexible Links for Unmodeled Environments”
- Jonathan Klamkin, Boston University; “HELIOS: Heterogeneous Laser Transmitter Integration for Low SWaP”
- Rebecca Kramer, Purdue University, West Lafayette, Indiana; “Active Elastic Skins for Soft Robotics”
Milestones continued...

• Carmel Majidi, Carnegie Mellon University, Pittsburgh; “Multi-Purpose Artificial Muscle and Sensor Array for Untethered Soft Robots”

Aligned with NASA’s Space Technology Roadmaps and priorities identified by the National Research Council, the agency has topic areas that lend themselves to the early stage innovative approaches U.S. universities can offer for solving tough space technology challenges. NASA’s Early Career Faculty efforts are an element of the agency’s Space Technology Research Grants Program. This program is designed to accelerate the development of technologies originating from academia that support the future science and exploration needs of NASA, other government agencies, and the commercial space sector.

**NASA Announces Education Research Program Award Recipients**

EPSCoR

Experimental Program to Stimulate Competitive Research

NASA is awarding $11.25 million to 15 colleges and universities across the United States to conduct basic research and technology development in areas including climate change, nanotechnology, astrophysics, aviation, and other areas relevant to the agency’s missions. The awards, each valued at $750,000, are made through NASA’s Experimental Program to Stimulate Competitive Research (EPSCoR).

One proposal was selected from each of the following universities and organizations: College of Charleston, South Carolina; Maine Space Grant Consortium; Montana State University, Bozeman; New Mexico State University; South Dakota School of Mines and Technology, Rapid City; University of Hawaii, Honolulu; University of Idaho, Moscow; University of Kentucky, Lexington; University of Mississippi, Oxford; University of Missouri, Rolla; University of Nebraska, Omaha; University of Nevada, Reno; University of Oklahoma, Norman; University of Puerto Rico, San Juan; and University of Vermont, Burlington.

EPSCoR is managed by NASA’s Office of Education. 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 institution’s economic viability and development.

**Neil A. Armstrong Commemorative Archive**

The University of Cincinnati (UC) has announced the release of a new website to commemorate the life and work of Neil Armstrong. Armstrong was a professor of aeronautical engineering at UC from 1971 to 1979.
Milestones continued...

The Neil Armstrong Commemoration consists of a beautiful and interactive website that includes a digital archive of images, documents, and texts, primarily from the university archives, relating to Armstrong’s teaching career at UC. Also included are selected significant artifacts and documents from Armstrong’s life beyond the university.

To view the website, visit digitalprojects.libraries.uc.edu/armstrong.
BOOKS

Incoming Asteroid: What Could We Do About It?

Lately there have been more news stories on objects from space — asteroids, comets, and meteors — whizzing past Earth. One even exploded in the atmosphere over a Russian city in 2012, causing real damage and injuries. Impacts are not uncommon in our solar system, even on Earth, and people are beginning to realize that we must prepare for such an event. What if we knew there was going to be an impact in 10 years’ time? What could we do? Lunan and his colleagues set out to explore how they could turn aside a rock asteroid, 1 kilometer (0.62 miles) in diameter, within this 10-year timescale. They identify the steps that might be taken, using technologies that are currently under development or proposed. They consider an unmanned mission, a follow-up manned mission, and a range of final options, along with ways to reduce the worst consequences for humanity if the impact cannot be prevented. With more warning, the techniques described could be adapted to deal with more severe threats, and, if successful, could generate the capability for a much expanded human presence in space thereafter. With the dangers now beginning to be recognized internationally and with major new programs already in motion, the prospects for civilization and humanity, in relation to the danger of impacts, look much more hopeful than they did only a decade ago.


Cassini-Huygens was the most ambitious and successful space journey ever launched to the outer solar system. This book examines all aspects of the mission: its conception and planning; the lengthy political processes needed to make it a reality; the engineering and development required to build the spacecraft; its 3.5-billion-kilometer (2.2-billion-mile) journey from Earth to Saturn; and the amazing discoveries from the mission. Author Meltzer traces how the visions of a few brilliant scientists matured, gained popularity, and eventually became a reality.

The New Moon: Water, Exploration, and Future Habitation.

Explore Earth’s closest neighbor, the Moon, in this fascinating and timely book and discover what we should expect from this seemingly familiar but strange, new frontier. What startling discoveries are being uncovered on the Moon? What will these tell us about our place in the universe? How can exploring the Moon benefit development on Earth? Discover the role of the Moon in Earth’s past and present; read about the lunar environment and how it could be made more habitable for humans; consider whether continued exploration of the Moon is justified; and view rare Apollo-era photos and film stills. This is a complete story of the human lunar experience, presenting many interesting but little-known and significant events in lunar science for the first time. It will appeal to anyone wanting to know more about the stunning discoveries being uncovered on the Moon.
History of the Planetary Systems from Thales to Kepler.

Originally published in 1906, this book presents a study of the history of man’s conception of the universe from the earliest historical ages to the completion of the Copernican system by Kepler in the seventeenth century. Detailed notes and illustrative figures are incorporated throughout. This book will be of value to anyone with an interest in planetary systems and the history of astronomy.

Edited by Tilman Spohn, Doris Breuer, and Torrence Johnson. Elsevier, 2014, 1336 pp., Hardcover, $180.00. store.elsevier.com

This third edition of the Encyclopedia of the Solar System provides a framework for understanding the origin and evolution of the solar system, historical discoveries, and details about planetary bodies and how they interact — with an astounding breadth of content and breathtaking visual impact. The encyclopedia includes the latest explorations and observations, hundreds of color digital images and illustrations, and more than 1000 pages. It stands alone as the definitive work in this field, and will serve as a modern messenger of scientific discovery and provide a look into the future of our solar system. New additions to the third edition reflect the latest progress and growth in the field, including past and present space missions to the terrestrial planets, the outer solar systems, and space telescopes used to detect extrasolar planets.

101 Objects to See in the Night Sky.

This book is a fun and practical guide to identifying and observing 101 of the most fascinating and exciting sights in the northern night sky. Designed for newcomers to astronomy, the book explains what can be seen using the naked eye, binoculars, or a telescope. Author and professional astronomer Scagell shows the novice astronomer where to look in the sky to see a particular object, or group of objects or sights. They may be a planet, its rings or satellites, a series of lunar craters, a constellation, asteroids, meteors, a nebula, a galaxy, or a star cluster. Informative “where to find it” instructions and “what you’ll see” explanations for each object give night sky viewers an extra hand, and a concise “fact file” is provided for each object. Organized by season and with an opening section on “things you need to know,” this book is an ideal guide for astronomy novices and classrooms and the perfect starter astronomy guide to night viewing.
New and Noteworthy continued . . .

DVD

Australia’s First 4 Billion Years.
Produced by NOVA/PBS, 2013, two discs. $29.99. www.shoppbs.org

Of all continents on Earth, none preserves a more spectacular story of its origins than Australia. With help from geologist Richard Smith, we meet titanic dinosaurs and giant kangaroos, sea monsters and prehistoric crustaceans, disappearing mountains, and deadly asteroids. Epic in scope and intimate in nature, this is the untold story of the Land Down Under, the one island continent that has it all.

FOR KIDS!!!

Earth, Mars and Moon Mobile to Scale Kit.
Produced by Shasta Visions. 2014, $29.00. www.shastavisions.com

This to-scale kinetic art sculpture includes a 1.4-inch Earth, a 1-inch Mars, and a 0.5-inch Moon, all made of recycled glass. An educational card, cosmic fun facts, and directions for assembly are included. All the components of the kit and packaging are environmentally friendly and made in the USA. It’s the perfect gift to inspire play, perspective, and peace. For ages 8 and up. (Note: Not for small children — small pieces may present a choking hazard.)

A Trip into Space: An Adventure to the International Space Station.

A lively, rhythmical story and detailed illustrations take readers on a trip to the International Space Station (ISS), where astronauts work, sleep, and walk in space. This great read-aloud includes the latest information (verified by NASA staff) about the ISS. Fact-filled and fun, this story will send young minds soaring. For ages 4 to 7.
**You Can’t Ride a Bicycle to the Moon.**


In *You Can’t Ride a Bicycle to the Moon*, kids will explore the science of the Moon, the space race, the craft of spacecraft, living in space, tourists in space, and a lot more. “What should I eat in space today? Something that won’t float away! Food that sticks onto a spoon is best when dining on the Moon.” Learn about the pioneering dogstronauts and how technology created for space affects our life on Earth. Each section begins with activities and kickstarter questions that expand a child’s understanding of the subject matter and how it applies to the wider world and his or her daily life. This book makes it personal and fun, and the science will captivate young readers. For ages 4 to 8.

**The Rock Cycle.**


Much of Earth is made up of rock, including the continents and even the melted rock of the planet’s core. Rock is present in all shapes, sizes, and compositions. Readers will learn about the natural processes involved in creating different kinds of rock. Accessible science content that supports the curriculum enhanced by colorful photographs will engage geology enthusiasts and curious minds alike. A simple graphic organizer and fact boxes full of more information add even more excitement for readers. For grades 2 to 3.
### Calendar 2014–2015

#### November

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<tr>
<td>6–7</td>
<td>Photonics for Planets, Florence, Italy. <a href="http://www.arcetri.astro.it/images/data/Workshops/PhotonicsForPlanets/">http://www.arcetri.astro.it/images/data/Workshops/PhotonicsForPlanets/</a></td>
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<tr>
<td>18–21</td>
<td>Star-Planet Interactions and the Habitable Zone, Saclay, France. <a href="http://irfu.cea.fr/habitability/">http://irfu.cea.fr/habitability/</a></td>
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#### December

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#### January 2015

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<tbody>
<tr>
<td>6–8</td>
<td>12th Meeting of the NASA Small Bodies Assessment Group (SBAG), Phoenix, Arizona. <a href="http://www.lpi.usra.edu/sbag/">http://www.lpi.usra.edu/sbag/</a></td>
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#### February

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<tr>
<td>11–13</td>
<td>Workshop on Collisions in the Solar System, Belgrade, Serbia. <a href="http://poincare.matf.bg.ac.rs/~bojan/ltw/ltw2.html">http://poincare.matf.bg.ac.rs/~bojan/ltw/ltw2.html</a></td>
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#### March

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<tr>
<td>15–18</td>
<td>Ringberg Workshop on Spectroscopy with the Stratospheric Observatory for Infrared Astronomy, Schloss Ringberg, Germany. <a href="https://indicodisplay.py?confld=93">https://indicodisplay.py?confld=93</a></td>
</tr>
<tr>
<td>23–27</td>
<td>Star and Planet Formation in the Southwest, Oracle, Arizona. <a href="https://lavinia.as.arizona.edu/~kkrafter/SPF1/Home.html">https://lavinia.as.arizona.edu/~kkrafter/SPF1/Home.html</a></td>
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#### April

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### May

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### June

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<tr>
<td>2–4</td>
<td>Workshop on the Formation of the Solar System II, Bonn, Germany.</td>
<td><a href="https://indico.mpifr-bonn.mpg.de/FormationOfTheSolarSystem2">https://indico.mpifr-bonn.mpg.de/FormationOfTheSolarSystem2</a></td>
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<tr>
<td>7–12</td>
<td>22nd ESA Symposium on European Rocket and Balloon Programmes and Related Research, Tromso, Norway.</td>
<td><a href="http://pac.spaceflight.esa.int">http://pac.spaceflight.esa.int</a></td>
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<tr>
<td>9–11</td>
<td>The International Academy of Astronautics (IAA) LCPM-11, Berlin, Germany.</td>
<td><a href="http://www.dlr.de/LCPM11">http://www.dlr.de/LCPM11</a></td>
</tr>
<tr>
<td>14–18</td>
<td>The Future and Science of Gemini Observatory, Toronto, Canada.</td>
<td><a href="http://www.gemini.edu/fsg15">http://www.gemini.edu/fsg15</a></td>
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### July

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### August

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<tr>
<td>17–21</td>
<td>Cosmic Dust, Tokyo, Japan.</td>
<td><a href="https://www.cps-jp.org/~dust/Welcome.html">https://www.cps-jp.org/~dust/Welcome.html</a></td>
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### October

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### November

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