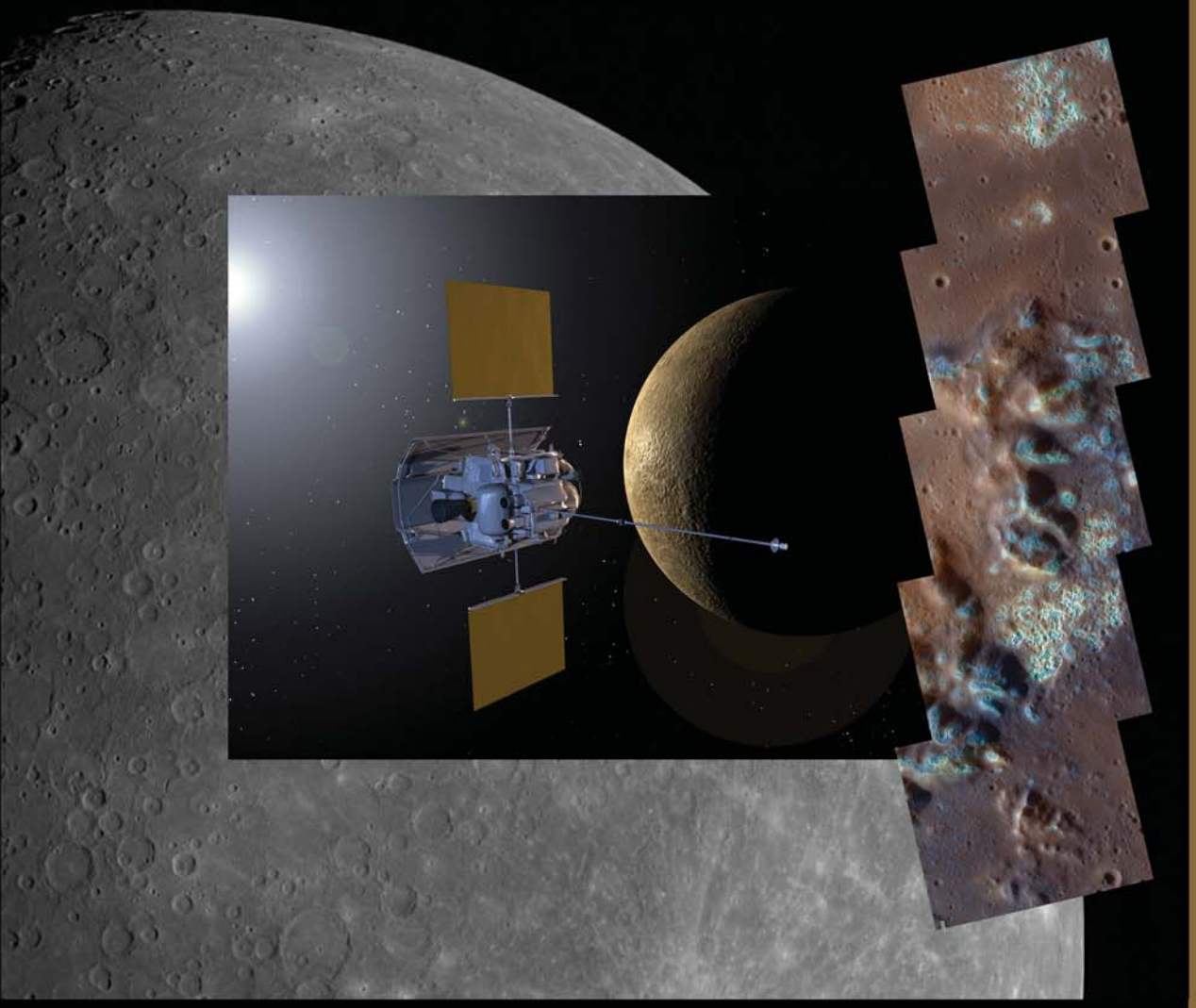
MESSENGER:
Revealing Mercury's Secrets



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MESSENGER: Revealing Mercury's Secrets

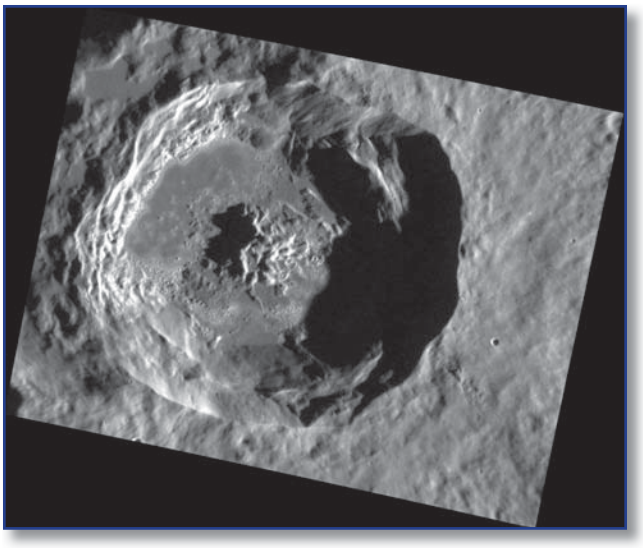
— Brett Denevi and Carolyn Ernst, The Johns Hopkins University Applied Physics Laboratory

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft was placed into orbit around Mercury on March 18, 2011, less than one year ago, and our understanding of the innermost planet has already been transformed. Prior to MESSENGER's first looks, our knowledge was limited to snapshots in time: six flybys of the planet, three each by Mariner 10 and MESSENGER. Mariner 10 launched in 1973 and, after a gravity assist from Venus, sent back the first close-up data from Mercury in 1974 and 1975. Less than half of the planet was imaged, however, leaving huge gaps in our picture of how Mercury formed and evolved. There was tantalizing evidence for volcanism on the surface, but not enough to settle the debate over how the plains on Mercury formed. Huge tectonic features suggested contraction of the crust on a hemispherical scale, but the history of the other hemisphere was unknown. Very little was known about the composition of the surface, the internal structure of the planet, or why it is so dense.

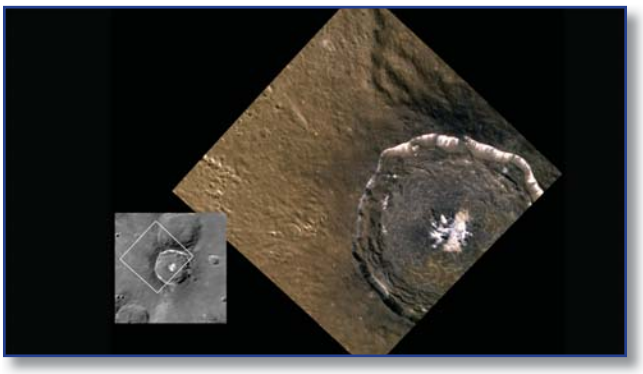
For over 30 years Mercury remained a mystery, with globes blank on one side and without the data to answer many of these basic questions. MESSENGER's flybys in 2008 and 2009 began to fill in the picture, providing the first images of the other side of the planet and finally allowing for global analyses. But not until MESSENGER's arrival in orbit did our view truly come into focus, revealing a unique and complex world. We now have the equivalent of two flybys every day. MESSENGER orbits Mercury once every 12 hours, coming as close as 200 kilometers from the surface in the northern hemisphere and swinging out to over 15,000 kilometers elevation in the south, allowing the spacecraft to cool down as it moves away from the hot dayside surface. This eccentric orbit means that the Mercury Laser Altimeter (MLA) cannot observe much of the southern hemisphere, other instruments yield southern-hemisphere measurements that are large-scale averages, and the highest-resolution images will always be in the north. But even with these observational constraints, we can now begin to assess with confidence Mercury's significance as the innermost member of our terrestrial family.

Schematic illustration of the operation of MESSENGER's Mercury Laser Altimeter (MLA). MLA ranges to Mercury whenever the spacecraft is within 1800 kilometers of the surface. Eight times per second, MLA's laser emits a short (5-nanosecond) pulse, which propagates along the laser transmitter's line of sight to the surface, where a fraction of the pulse energy is reflected from the surface and propagates back to MLA's four receiver telescopes. The time of flight of the laser pulse provides the distance to the portion of the surface from which the signal was reflected. Credit: NASA/The Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

Since MESSENGER entered orbit, the Mercury Dual Imaging System (MDIS) cameras have taken over 60,000 images covering over 99% of Mercury's surface, some at resolutions as good as 10 meters/pixel. Flyby imaging hinted at the existence of volcanic plains toward Mercury's north pole, but MESSENGER's global imaging has documented extensive volcanism across the planet, including an expanse of relatively young volcanic plains at high northern latitudes equal in area to nearly two-thirds the size of the continental United States. High-resolution images have revealed "hollows," unexpected geologic landforms that may be among the youngest



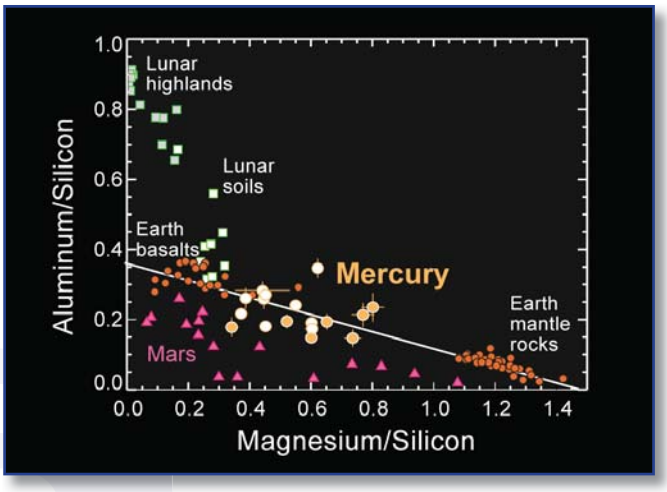
This stunning, and as of yet unnamed, crater lies within the Caloris basin. Its floor provides another example of the beautiful "hollows" found on Mercury and has an etched appearance similar to that found in other young craters (see also the front cover for a high-resolution view of Mercury's "hollows"). Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.



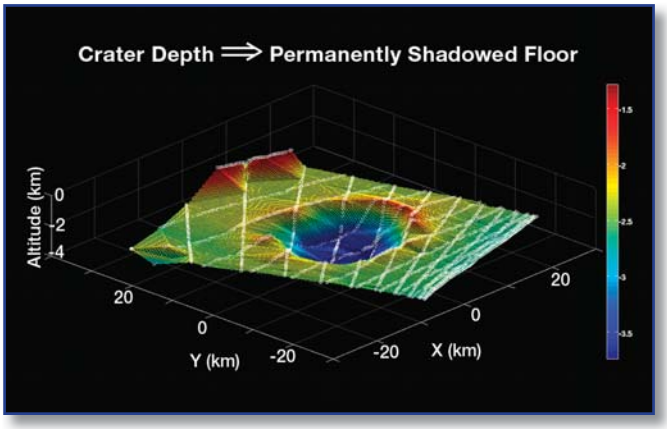
This spectacular view of the crater Degas was obtained as a high-resolution targeted observation (90 m/pixel). Impact melt coats its floor, and as the melt cooled and shrank, it formed the cracks observed across the crater. For context, Mariner 10's view of Degas is shown at left. Degas is 52 km in diameter and is centered at 37.1°N, 232.8°E. Credit: NASA/The Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

features on the surface. These hollows are shallow, irregular depressions often surrounded by bright halos and are found across the globe, usually associated with rocks excavated from depth by the crater-forming process (crater central peaks, peak rings, floors, and walls). One formation mechanism involves the loss of volatile material, possibly by sublimation. The hollows support the implication that Mercury's interior contains higher abundances of volatiles than previously thought — especially surprising given Mercury's proximity to the Sun. MESSENGER images confirmed the dominantly contractional deformation of Mercury's crust, with huge lobate scarps and associated fault systems having deformed the crust across the globe. An exciting discovery is the existence of dozens of areas of local extension, primarily within craters and basins, another indicator of Mercury's complex geologic history.

Some of the most intriguing new results are coming from the geochemical measurements made by MESSENGER's X-Ray Spectrometer (XRS) and Gamma-Ray Spectrometer (GRS). The prevailing paradigm for many years was that Mercury's crust was similar to the anorthositic lunar highlands and represented an early crust formed by plagioclase flotation in a global magma ocean. Images from MESSENGER's flybys suggested that the geology was actually quite different, with much of the crust having formed through volcanic eruptions. But the XRS and GRS observations from orbit have confirmed that Mercury is truly not the Moon: The crust has much lower aluminum/silicon and calcium/silicon ratios and higher magnesium/silicon ratios. In this regard Mercury's crust is more similar in places to the lunar maria, but with two major differences: Surface abundances of iron and titanium are extremely low on Mercury. In other places Mercury's surface appears to be more similar to rocks formed from magmas that once erupted very early in Earth's history, the high-magnesium and low-silicon komatiites. Another surprise is the high abundance of sulfur detected on the surface, at least 10 times higher than found on surfaces of Earth or the Moon, which implies that Mercury formed in a highly reducing environment. The formation and early evolution of Mercury is also now informed by measurements



Major-element composition of Mercury's surface materials, depicted on the same graph, as measured by the MESSENGER XRS. Mercury has lower Al/Si and higher Mg/Si than typical lunar surface materials and terrestrial basalts, indicating a lower fraction of the common mineral plagioclase feldspar. Credit: NASA/The Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

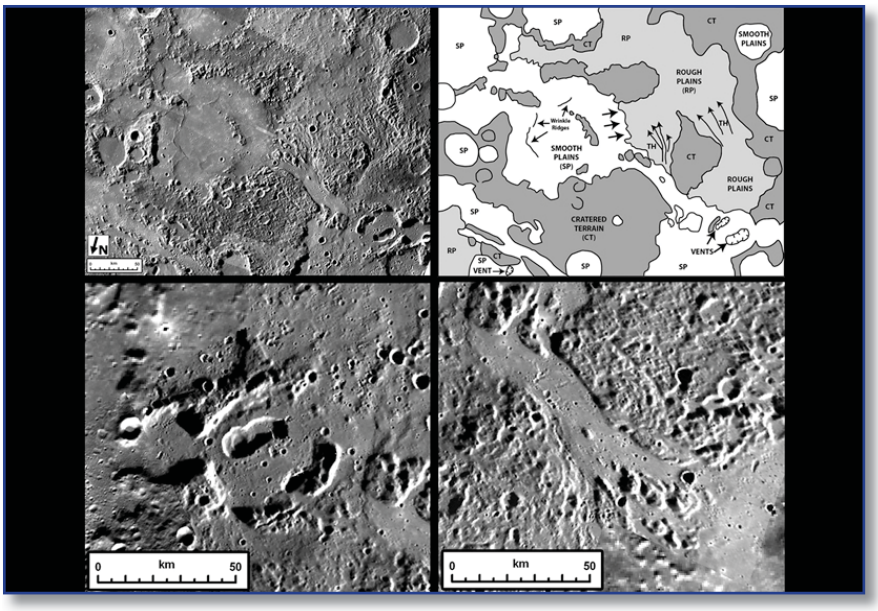


This topographic contour map was constructed from the several MLA profiles (lines of white circles) that pass through and near a prominent impact crater. The color scale at right is in kilometers, and north is at the four o'clock position. Calculations show that the topography of the crater is consistent with the prediction that the southernmost portion of the crater floor is in permanent shadow. Credit: NASA/ The Johns Hopkins University Applied Physics Laboratory/ Carnegie Institution of Washington.

of the surface abundances of radioactive elements from GRS. These data show that the abundance of the moderately volatile element potassium is as high relative to the refractory elements thorium and uranium as on Mars or Earth, suggesting that extreme and sustained heating such as from a giant impact or vaporization by an early hot solar nebula cannot account for Mercury's high density.

Mercury's geophysical story is also beginning to emerge. Topographic measurements from MLA show a planet with large long-wavelength topographic variations. A substantial lowlands that hosts the northern volcanic plains is on average 2 kilometers lower than the surrounding area but is not the result of any one basin-forming impact. The topography of Caloris basin has also been heavily modified since formation and interior plains emplacement, rendering it nearly unrecognizable on an elevation map. New results for Mercury's gravity field are also providing surprises. The Mariner 10 and MESSENGER flybys yielded different estimates for the value for C20, the polar flattening of the gravity field and an important quantity for understanding the nature of Mercury's core. Prior to orbit insertion, MESSENGER's Geophysics Discipline Group conducted a friendly pool to guess the correct value for C20. The winner: P.I. Sean Solomon (a close runner-up was NASA administrator Charles Bolden). The detailed work of interpreting the internal structure of Mercury is underway.

Although MESSENGER's primary mission will end on March 17, 2012, NASA recently announced that they would extend the mission by one Earth year, through March 17, 2013. The extended mission is designed to answer scientific questions that have arisen only after discoveries made from orbit: What are the sources of Mercury's surface volatiles? How recently was Mercury volcanically active? How has the long-wavelength topography of the planet evolved? These questions will be pursued through continued collection of data from all of MESSENGER's instruments,



Candidate volcanic vents, lava flow-related channels, and teardrop-shaped features. Upper left and right: Image and sketch map of the assemblage of volcanic flow-related features. Lower left: Pits interpreted as source vents. Lower right: Teardrop-shaped hills and channel interpreted to be formed by lava erosion. Credit: Courtesy of *Science*/AAAS.

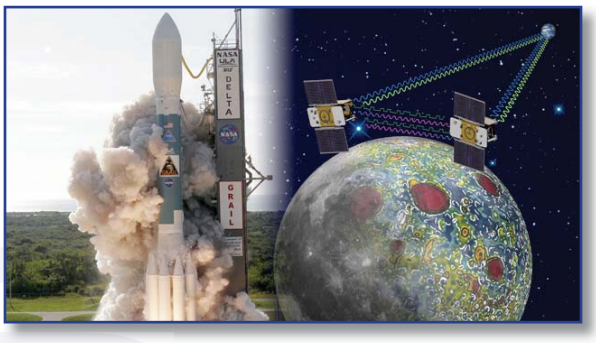
including many more targeted observations and images. On the basis of the exciting results of the primary mission to date, Mercury has many more secrets waiting to be discovered!

About the Authors:

Carolyn Ernst (pictured left) is a Staff Scientist in the Space Department of The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland (APL). Her main research focuses on impact cratering, including such topics as experimental impact flash photometry, using crater ejecta to probe subsurface stratigraphy, and small body crater morphology and modification. She is the primary sequencer for the Mercury Laser Altimeter (MLA) and also works on calibration and data analysis for the Mercury Dual Imaging System (MDIS), both onboard the MESSENGER spacecraft. She received her Ph.D. in geology from Brown University.

Brett W. Denevi (pictured right) is also a Staff Scientist in the Space Department of APL. Her research focuses on the composition, origin, and evolution of planetary and asteroidal surfaces, including topics such as regolith development, chemical and mineralogic composition of planetary materials as derived from ultraviolet, visible, and near-infrared spectroscopy, and geologic mapping of planetary surfaces. She has extensive experience in sensor calibration and image processing. She is currently working on the calibration and analysis of images from MESSENGER's Mercury Dual Imaging System (MDIS), and she is a Co-Investigator on the Lunar Reconnaissance Orbiter Camera and a Participating Scientist on the Dawn mission to Vesta. She received her Ph.D. in geology and geophysics from the University of Hawaii.

NASA Launches Mission to Study Moon from Crust to Core



NASA's GRAIL spacecraft successfully launched from Cape Canaveral Air Force Station on September 10, 2011. As depicted in the artist's concept on the right, the twin spacecraft, GRAIL-A and GRAIL-B, will work in tandem to study the lunar interior, from crust to core, and to advance understanding of the thermal evolution of the Moon. Credit: NASA/JPL-Caltech/ Thom Baur, United Launch Alliance.

NASA's twin lunar Gravity Recovery and Interior Laboratory (GRAIL) spacecraft lifted off from Cape Canaveral Air Force Station in Florida at 9:08 a.m. EDT (6:08 a.m. PDT) Saturday, September 10, to study the Moon in unprecedented detail. GRAIL-A is scheduled to reach the Moon on New Year's Eve 2011, while GRAIL-B will arrive New Year's Day 2012. The two solar-powered spacecraft will fly in tandem orbits around the Moon to measure its gravity field. GRAIL will answer longstanding questions about the Moon and give scientists a better understanding of how Earth and other rocky planets in the solar system formed.

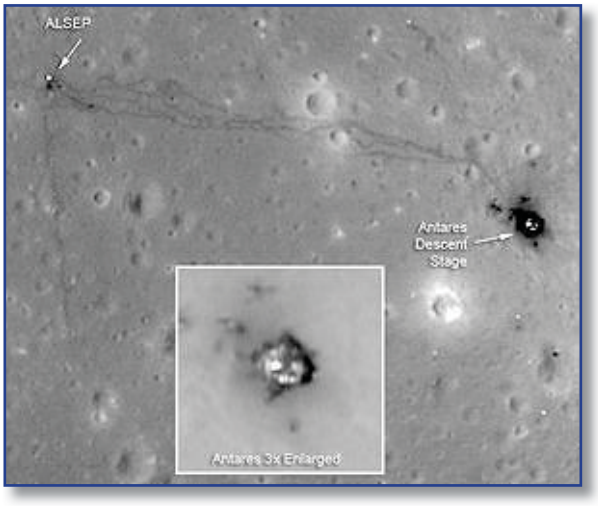
The spacecraft were launched onboard a United Launch Alliance Delta II rocket. GRAIL mission controllers acquired a signal from GRAIL-A at 10:29 a.m. EDT (7:29 a.m. PDT). GRAIL-B's signal was received eight minutes later. The telemetry downlinked from both spacecraft indicates they have deployed their solar panels and are operating as expected.

The straight-line distance from Earth to the Moon is approximately 250,000 miles (402,336 kilometers). NASA's Apollo Moon crews needed approximately three days to cover that distance. However, each GRAIL spacecraft will take approximately 3.5 months to arrive, covering more than 2.5 million miles (4 million kilometers) along the way. This low-energy trajectory results in the longer travel time for spacecraft check-out and time to update plans for lunar operations. The science collection phase for GRAIL is expected to last 82 days.

"Since the earliest humans looked skyward, they have been fascinated by the Moon," said GRAIL principal investigator Maria Zuber from the Massachusetts Institute of Technology in Cambridge. "GRAIL will take lunar exploration to a new level, providing an unprecedented characterization of the Moon's interior that will advance understanding of how the Moon formed and evolved." For more information about GRAIL, visit *www.nasa.gov/grail* or *solarsystem.nasa.gov/grail*.

NASA Spacecraft Images Offer Sharper Views of Apollo Landing Sites

NASA's Lunar Reconnaissance Orbiter (LRO) captured the sharpest images ever taken from space of the Apollo 12, 14 and 17 landing sites. Images show the twists and turns of the paths made when the astronauts explored the lunar surface. At the Apollo 17 site, the tracks laid down by the lunar



The paths left by astronauts Alan Shepard and Edgar Mitchell on both Apollo 14 moon walks are visible in this image. (At the end of the second moon walk, Shepard famously hit two golf balls.) The descent stage of the lunar module Antares is also visible. Credit: NASA's Goddard Space Flight Center/ASU.

rover are clearly visible, along with the last foot trails left on the Moon. The images also show where the astronauts placed some of the scientific instruments that provided the first insight into the Moon's environment and interior.

All three images show distinct trails left in the Moon's thin soil when the astronauts exited the lunar modules and explored on foot. In the Apollo 17 image, the foot trails, including the last path made on the Moon by humans, are easily distinguished from the dual tracks left by the lunar rover, which remains parked east of the lander. "The new low-altitude Narrow Angle Camera images sharpen our view of the Moon's surface," said Arizona State University researcher Mark Robinson, principal investigator for the Lunar Reconnaissance Orbiter Camera (LROC). "A great example is the sharpness of the rover tracks at the Apollo 17 site. In previous images the rover tracks were visible, but now they are sharp parallel lines on the surface."

At each site, trails also run to the west of the landers, where the astronauts placed the Apollo Lunar Surface Experiments Package (ALSEP) to monitor the Moon's environment and interior. This equipment was a key part of every Apollo mission. It provided the first insights into the Moon's internal structure, measurements of the lunar surface pressure and the composition of its atmosphere. Apollo 11 carried a simpler version of the science package.

The higher resolution of these images is possible because of adjustments made to LRO's orbit, which is slightly oval-shaped or elliptical. "Without changing the average altitude, we made the orbit more elliptical, so the lowest part of the orbit is on the Sun-lit side of the Moon," said Goddard's John Keller, deputy LRO project scientist. "This put LRO in a perfect position to take these new pictures of the surface." The maneuver lowered LRO from its usual altitude of approximately 31 miles (50 kilometers) to an altitude that dipped as low as nearly 13 miles (21 kilometers) as it passed over the Moon's surface. The spacecraft remained in this orbit for 28 days, long enough for the Moon to completely rotate. This allowed full coverage of the surface by LROC's Wide Angle Camera.

"These images remind us of our fantastic Apollo history and beckon us to continue to move forward in exploration of our solar system," said Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington. To learn more about LRO, visit *www.nasa.gov/lro*.

NASA Launches Most Capable and Robust Rover to Mars

NASA began a historic voyage to Mars with the November 26 launch of the Mars Science Laboratory (MSL), which carries a car-sized rover named Curiosity. Liftoff from Cape Canaveral Air Force Station onboard an Atlas V rocket occurred at 10:02 a.m. EST (7:02 a.m. PST). "We are very excited about sending the world's most advanced scientific laboratory to Mars," NASA Administrator Charles Bolden said. "MSL will tell us critical things we need to know about Mars, and while it advances science, we'll be working on the capabilities for a human mission to the Red Planet and to other destinations where we've never been."

NASA's Mars Science Laboratory spacecraft, sealed inside its payload fairing atop the United Launch Alliance Atlas V rocket, clears the tower at Space Launch Complex 41 on Cape Canaveral Air Force Station in Florida. Credit: United Launch Alliance.

The mission will pioneer precision landing technology and a sky-crane touchdown to place Curiosity near the foot of a mountain inside Gale Crater on August 6, 2012. During a nearly two-year prime mission after landing, the rover will investigate whether the region has ever offered conditions favorable for microbial life, including the chemical ingredients for life.

Curiosity's ambitious science goals are among the mission's many differences from earlier Mars rovers. It will use a drill and scoop at the end of its robotic arm to gather soil and powdered samples of rock interiors, then sieve and parcel out these samples into analytical laboratory instruments inside the rover. Curiosity carries 10 science instruments with a total mass 15 times as large as the science-instrument payloads on the Mars rovers Spirit and Opportunity. Some of the tools are the first of their kind on Mars, such as a laser-firing instrument for checking the elemental composition of rocks from a distance, and an X-ray diffraction instrument for definitive identification of minerals in powdered samples. To haul and wield its science payload, Curiosity is twice as long and five times as heavy as Spirit or Opportunity. Because of its one-ton mass, Curiosity is too heavy to employ airbags to cushion its landing as previous Mars rovers could. Part of the MSL spacecraft is a rocket-powered descent stage that will lower the rover on tethers as the rocket engines control the speed of descent.

The mission's landing site offers Curiosity access for driving to layers of the mountain inside Gale Crater. Observations from orbit have identified clay and sulfate minerals in the lower layers, indicating a wet history. Precision landing maneuvers as the spacecraft flies through the martian atmosphere before opening its parachute make Gale a safe target for the first time. This innovation shrinks the target area to less than one-fourth the size of earlier Mars landing targets. Without it, rough terrain at the edges of Curiosity's target would make the site unacceptably hazardous.

The innovations for landing a heavier spacecraft with greater precision are steps in technology development for human Mars missions. In addition, Curiosity carries an instrument for monitoring the natural radiation environment on Mars, important information for designing human Mars missions that protect astronauts' health. For more information, visit *www.nasa.gov/msl/* or *marsprogram.jpl.nasa.gov/msl/*.

Phobos-Grunt Mars Probe Loses Its Way

The long-awaited return of the Russians into the solar system will have to wait even longer. The European Space Agency (ESA) has given up on efforts to revive Phobos-Grunt, the Russian space probe that was slated to visit the martian moon Phobos. Shortly after launch on November 9, subsequent rocket burns intended to set the craft on a course for Mars failed, leaving the spacecraft stranded in low-Earth orbit. The mission of the unmanned probe was to take soil samples from the martian moon and fly them to Earth. Potato-shaped Phobos is a fascinating target. Although it has been studied extensively by passing satellites, it still holds many secrets — not just about itself, but also the planet below. One of two moons at Mars (the other being Deimos), its extremely low density indicates that the body has many interior voids. Scientists hoped the dusty debris would provide fresh insights into the origin of the 27-km-wide moon, which many scientists suspect may actually be a captured asteroid or a collection of rocky rubble that coalesced around the Red Planet soon after its formation.

Phobos-Grunt was also significant because it was carrying China's first Mars satellite, Yinghuo-1, which was riding piggyback on the mission. The French (CNES) and German (DLR) space agencies provided instrumentation for the mission, and the European Space Agency (ESA), in addition to survey information from Mars Express, was to provide ground support. U.S. participation was from the space advocacy group, The Planetary Society, which sent its Living Interplanetary Flight Experiment (LIFE), which would have tested theories on how living organisms could spread through the solar system by simulating aspects of the long-duration voyage that microbes could make in a meteoroid that has been blasted off one planetary body and landed on another.

All efforts from ESA to send the probe commands that could send it to the next stage of its mission have been unsuccessful, and ESA has announced it will not be making further attempts to contact the probe. Scientists expect the 13.2-ton spacecraft to fall back to Earth sometime in January. According to NASA veteran James Oberg, the probe could be the "most toxic falling satellite ever," as most of its weight consists of highly toxic hydrazine and nitrogen tetroxide fuel. If the fuel has frozen in space, some of it could survive the fall to Earth, but if it is still liquid, it will probably burn away — along with the rest of the probe — when reentering the atmosphere.

Craters formed on the surfaces of planetary bodies, including the Earth, by high-speed impacts, are a basic landform on all the solid planets in the solar system.

NASA Partners Uncover New Hypothesis on Crater Debris

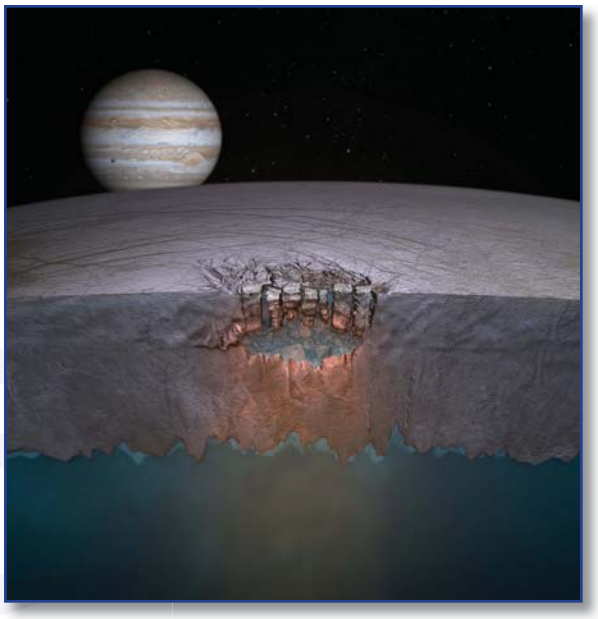
A team of researchers partnered with the NASA Lunar Science Institute (NLSI) has developed a new hypothesis for the origin of crater ejecta — debris that is launched out of a crater during meteorite impacts. These findings may help scientists target samples for extraction during future missions to asteroids and terrestrial bodies such as Mercury, Venus, the Moon, and Mars. The results were published in the September 21 issue of the journal *Earth and Planetary Science Letters*.

The science team, led by professor Gordon Osinski at The University of Western Ontario, London, Ontario, compared observations of ejecta from all terrestrial planets. The observations showed that ejecta deposits all contained more than one layer. "Understanding ejecta is critical for understanding the context of samples collected by humans and robots during previous missions and may aid in targeting future sample return missions to the Moon, Mars, and beyond," said Osinski.

Craters formed on the surfaces of planetary bodies, including the Earth, by high-speed impacts are a basic landform on all the solid planets in the solar system. In prevailing models, a continuous sheet of ejected material forms during the excavation stage of cratering. Osinski and his team suggest that this stage is followed by a second major episode of ejecta emplacement during the final moments of crater formation — something that has not been taken into account in any previous models of crater formation. This second episode takes the form of flows of material molten by the impact event, which originates from deeper below the surface, potentially offering a unique window into planetary interiors. A more thorough understanding of the composition of planetary interiors reveals important insights into the history of how our solar system formed.

Scientists Find Evidence for Subsurface "Great Lake" On Europa

In a finding of significance in the search for life beyond Earth, scientists have discovered what appears to be a body of liquid water the volume of the North American Great Lakes locked inside the icy shell of Jupiter's moon Europa — which could represent a new potential habitat for life. Many more such lakes exist throughout the shallow regions of Europa's shell, the researchers predict in a November online article in the journal *Nature*. Further increasing the potential for life, many of these lakes are covered by floating ice shelves that seem to be collapsing, providing a mechanism for transferring nutrients and energy between the surface and a vast ocean already thought to exist below the thick ice shell.



Artist's impression of the "Great Lake" on Jupiter's moon Europa. Scientists speculate many more exist throughout the shallow regions of the moon's icy shell. Credit: Britney Schmidt/Dead Pixel FX/ University of Texas at Austin.

"The potential for exchange of material between the surface and subsurface is a big key for astrobiology," says Wes Patterson, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, and a co-author of the study. "Europa's subsurface harbors much of what we believe is necessary for life but chemical nutrients found at the surface are likely vital for driving biology."

"One opinion in the scientific community has been, 'If the ice shell is thick, that's bad for biology — that it might mean the surface isn't communicating with the underlying ocean," adds Britney Schmidt, the paper's lead author and a postdoctoral fellow at The University of Texas at Austin's (UT) Institute for Geophysics. "Now we see evidence that it's a thick ice shell that can mix vigorously, and new evidence for giant shallow lakes. That could make Europa and its ocean more habitable."

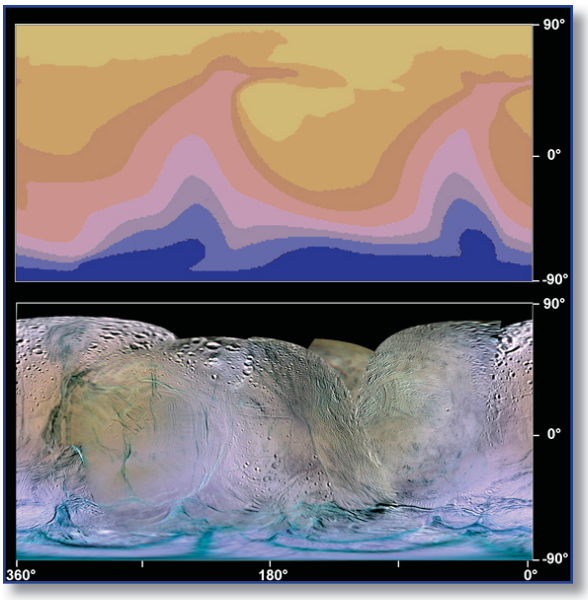
Besides Patterson and Schmidt, the other co-authors of the paper are Don Blankenship, senior research scientist at UT's Institute for Geophysics, and Paul Schenk, planetary scientist at the Lunar and Planetary Institute in Houston.

The scientists focused on Galileo spacecraft images of two roughly circular, bumpy features on Europa's surface called chaos terrains. Based on similar processes seen here on Earth — on ice shelves and under glaciers overlaying volcanos — they developed a four-step model to explain how the features form on Europa. It resolves several conflicting observations, some of which seemed to suggest that the ice shell is thick and others that it is thin.

While one of the chaos terrains appears to be fully formed, the other might still be forming — an indication that Europa's surface is still geologically active. "For quite some time, Europa geologists have been struggling to figure out what these features are and how they form," says APL's Louise Prockter, a senior planetary scientist who has conducted numerous studies of Europa. "This is the first time that anyone has come up with an end-to-end model that explains what we see on the surface."

The scientists have good reason to believe their model is correct, based on observations of Europa from the Galileo spacecraft and of Earth. Still, because the inferred lakes are several kilometers below the surface, the only true confirmation of their presence would come from a future spacecraft mission designed to probe the ice shell. Such a mission was rated as one of the highest-priority flagship missions by the National Research Council's recent Planetary Science Decadal Survey and is currently being studied by NASA.

The full article is available on the *Nature* website at *www.nature.com/nature/journal/vaop/ncurrent/full/nature10608.html*.



Global signature of frost deposition on Enceladus revealed in color mapping. The top map shows a colorized map of the predicted pattern of fallout from Enceladus's icy plumes, with the global color patterns observed by Cassini imaging camera. The bottom map is the global three-color map of Enceladus showing areas that are relatively bluer. These areas correspond very well with areas predicted to have a deeper accumulation of plume-generated ice particles, or "snow." The global color map takes advantage of Cassini's sensitivity at ultraviolet and near-infrared wavelengths and shows an enhanced color sensitivity compared to what our eyes might see. Plume deposition map from S. Kempf and J. Schmidt; global color map from P. Schenk.

Enceladus Weather: Snow Flurries and Perfect Powder for Skiing

Global and high resolution mapping of Enceladus confirms that the weather forecast for Saturn's unique icy moon is set for ongoing snow flurries. The superfine ice crystals that coat Enceladus's surface would make perfect powder for skiing, according to Dr. Paul Schenk of the Lunar and Planetary Institute, who presented the results at the EPSC-DPS Joint Meeting 2011 in Nantes, France, on Monday, October 3.

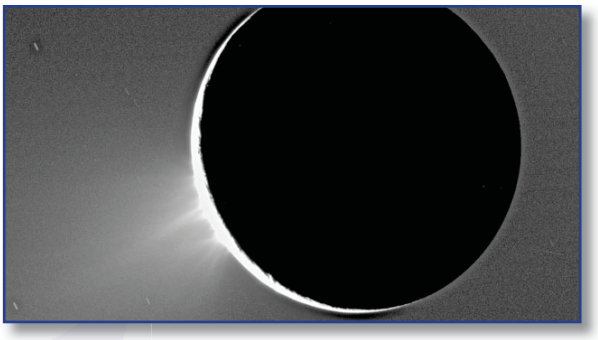
Mapping of global color patterns and measurements of surface layer thicknesses show that ice particles fall back onto the surface of Enceladus in a predictable pattern. Mapping of these deposits indicate that the plumes and their heat source are relatively long-lived features lasting millennia and probably tens of million years or more, and have blanketed areas of the surface in a thick layer of tiny ice particles.

"The discovery by instruments aboard the Cassini orbiter that there's a currently active plume of icy dust and vapor from Enceladus has revolutionized planetary science," says Schenk. "Earlier this year, we published work that showed material from Enceladus's plumes coats the surfaces of Saturn's icy moons. Now, we've uncovered two lines of evidence that point to thick deposits of plume material coating the surface of Enceladus itself."

Models of plume particle trajectories under the influence of Saturn's gravity show that some particles return to Enceladus in a distinctive pattern. This work by Dr. Sasha Kempf of the Max Planck Institute and Dr. Juergen Schmidt and colleagues at the University of Potsdam, published in 2010, predicts that the heaviest accumulation will be along two longitudes on opposite sides of the satellite. Global color mapping of Enceladus by Schenk and colleagues also shows a globally symmetric pattern of bluish material along two longitudes on opposite sides of the satellite. Comparison of these two maps shows a very close correspondence in the predicted and observed patterns, confirming the prediction of particle deposition on the surface of Enceladus.

Confirmation of plume fallout led Schenk and colleagues to search for physical evidence of plume particle accumulation on the surface. They examined the highest-resolution images north of the plume formation sites; the best of these has a resolution of 12 meters. The image reveals unusually smooth terrains with ghost-like topographic undulations indicating burial of older fractures and craters. Mapping the topography of the site at high resolution, they also found changes in slope along the rims of many of the deeper fractures, or canyons. The larger of these canyons are 500 meters (1650 feet) deep and 1.5 kilometers across, not unlike the Black Canyon of the Gunnison in Colorado. These breaks in slope occur approximately 75 to 125 meters below the rims of the canyon walls and correspond to elevations where more rugged crustal material is exposed part way down the canyon walls.

To read the full article, go to *www.spaceref.com/news/viewpr.html?pid=34837*.



Recent Cassini images of Saturn's moon Enceladus backlit by the Sun show the fountain-like sources of the fine spray of material that towers over the south polar region. This image was taken looking more or less broadside at the "tiger stripe" fractures observed in earlier Enceladus images. It shows discrete plumes of a variety of apparent sizes above the limb (edge) of the moon. Credit: NASA/JPL/Space Science Institute.

Saturn's Moon Enceladus Spreads Its Influence

Chalk up one more feat for Saturn's intriguing moon Enceladus. The small, dynamic moon spews out dramatic plumes of water vapor and ice — first seen by NASA's Cassini spacecraft in 2005. It possesses simple organic particles and may house liquid water beneath its surface. Its geyser-like jets create a gigantic halo of ice, dust, and gas around Enceladus that helps feed Saturn's E ring. Now, thanks again to those icy jets, Enceladus is the only moon in our solar system known to influence substantially the chemical composition of its parent planet.

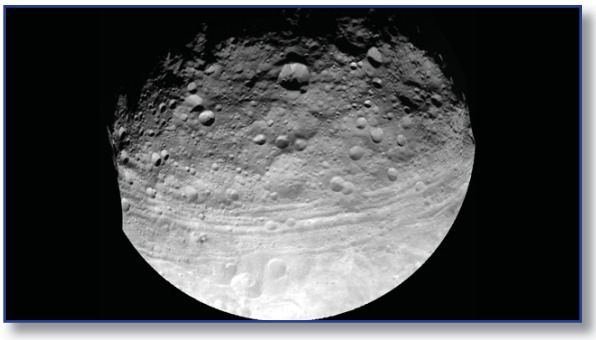
Last June, the European Space Agency (ESA) announced that its Herschel Space Observatory, which has important NASA contributions, had found a huge donut-shaped cloud, or torus, of water vapor created by Enceladus encircling Saturn. The torus is more than 373,000 miles (600,000 kilometers) across and about 37,000 miles (60,000 kilometers) thick. It appears to be the source of water in Saturn's upper atmosphere. Although it is enormous, the cloud had not been seen before because water vapor is transparent at most visible wavelengths of light. But Herschel could see the cloud with its infrared detectors.

The discovery of the torus around Saturn did not come as a complete surprise. NASA's Voyager and Hubble missions had given scientists hints of the existence of water-bearing clouds around Saturn. Then in 1997, ESA's Infrared Space Observatory confirmed the presence of water in Saturn's upper atmosphere. NASA's Submillimeter Wave Astronomy Satellite also observed water emission from Saturn at far-infrared wavelengths in 1999.

While a small amount of gaseous water is locked in the warm, lower layers of Saturn's atmosphere, it can't rise to the colder, higher levels. To get to the upper atmosphere, water molecules must be entering Saturn's atmosphere from somewhere in space. But from where and how? Those were mysteries until now.

Build the model and the data will come. The answer came by combining Herschel's observations of the giant cloud of water vapor created by Enceladus' plumes with computer models that researchers had already been developing to describe the behavior of water molecules in clouds around Saturn. One of these researchers is Tim Cassidy, a recent post-doctoral researcher at JPL who is now at the University of Colorado's Laboratory for Atmospheric and Space Physics, Boulder. "What's amazing is that the model," said Cassidy, "which is one iteration in a long line of cloud models, was built without knowledge of the observation. Those of us in this small modeling community were using data from Cassini, Voyager, and the Hubble telescope, along with established physics. We weren't expecting such detailed 'images' of the torus, and the match between model and data was a wonderful surprise."

The results show that, although most of the water in the torus is lost to space, some of the water molecules fall and freeze on Saturn's rings, while a small amount — about 3–5% — gets through the rings to Saturn's atmosphere. This is just enough to account for the water that has been observed there.



This full view of the giant asteroid Vesta was taken by NASA's Dawn spacecraft, as part of a rotation characterization sequence on July 24, 2011, at a distance of 3200 miles (5200 kilometers). A rotation characterization sequence helps the scientists and engineers by giving an initial overview of the character of the surface as Vesta rotated underneath the spacecraft. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

Dawn Science Team Presents Early Science Results

Scientists with NASA's Dawn mission are sharing with other scientists and the public their early information about the southern hemisphere of the giant asteroid Vesta. The findings were presented on October 12 at the annual meeting of the Geological Society of America in Minneapolis, Minnesota. Dawn, which has been orbiting Vesta since mid-July, has found that the asteroid's southern hemisphere boasts one of the largest mountains in the solar system. Other findings show that Vesta's surface, viewed by Dawn at different wavelengths, has striking diversity in its composition, particularly around craters. Science findings also include an in-depth analysis of a set of equatorial troughs on Vesta and a closer look at the object's intriguing craters. The surface appears to be much rougher than most asteroids in the main asteroid belt. In addition, preliminary dates from a method that uses the number of craters indicate that areas in the southern hemisphere are as young as 1 billion to 2 billion years old, much younger than areas in the north. Scientists do not yet understand how all the features on Vesta's surface formed, but they did announce, after analysis of northern and southern troughs, that results are consistent with models of fracture formation due to giant impact.

Since July, the Dawn spacecraft has been spiraling closer and closer to Vesta, moving in to get better and better views of the surface. In early August, the spacecraft reached an orbital altitude of 1700 miles (2700 kilometers) and mapped most of the sunlit surface, during survey orbit, with its framing camera and visible and infrared mapping spectrometer. That phase was completed in late August, and the spacecraft began moving in to what is known as the High Altitude Mapping Orbit (HAMO) at about 420 miles (680 kilometers) above Vesta, which it reached on September 29.

Dawn launched in September 2007 and arrived at Vesta on July 15, 2011. Following a year at Vesta, the spacecraft will depart in July 2012 for the dwarf planet Ceres, where it will arrive in 2015. For more information, visit *www.nasa.gov/dawn* or *dawn.jpl.nasa.gov*.

Origin of Dinosaur-Killing Asteroid Remains a Mystery

Observations from NASA's Wide-field Infrared Survey Explorer (WISE) mission indicate the family of asteroids some believed was responsible for the demise of the dinosaurs is not likely the culprit, keeping open the case on one of Earth's greatest mysteries.

While scientists are confident a large asteroid crashed into Earth approximately 65 million years ago, leading to the extinction of dinosaurs and some other life forms on our planet, they do not know exactly where the asteroid came from or how it made its way to Earth. A 2007 study using visible-light data from groundbased telescopes first suggested the remnant of

Scientists think that a giant asteroid, which broke up long ago in the main asteroid belt between Mars and Jupiter, eventually made its way to Earth and led to the extinction of the dinosaurs. This artist's concept shows a broken-up asteroid. Credit: NASA/JPL-Caltech.

a huge asteroid, known as Baptistina, as a possible suspect. According to that theory, Baptistina crashed into another asteroid in the main belt between Mars and Jupiter about 160 million years ago. The collision sent shattered pieces as big as mountains flying. One of those pieces was believed to have impacted Earth, causing the dinosaurs' extinction.

Since this scenario was first proposed, evidence developed that the so-called Baptistina family of asteroids was not the responsible party. With the new infrared observations from WISE, astronomers say Baptistina may finally be ruled out.

"As a result of the WISE science team's investigation, the demise of the dinosaurs remains in the cold case files," said Lindley Johnson, program executive for the Near Earth Object (NEO) Observation Program at NASA Headquarters in Washington. "The original calculations with visible light estimated the size and reflectivity of the Baptistina family members, leading to estimates of their age, but we now know those estimates were off. With infrared light, WISE was able to get a more accurate estimate, which throws the timing of the Baptistina theory into question."

WISE surveyed the entire celestial sky twice in infrared light from January 2010 to February 2011. The asteroid-hunting portion of the mission, called NEOWISE, used the data to catalogue more than 157,000 asteroids in the main belt and discovered more than 33,000 new ones.

Visible light reflects off an asteroid. Without knowing how reflective the surface of the asteroid is, it's hard to accurately establish size. Infrared observations allow a more accurate size estimate. They detect infrared light coming from the asteroid itself, which is related to the body's temperature and size. Once the size is known, the object's reflectivity can be re-calculated by combining infrared with visible-light data. The NEOWISE team measured the reflectivity and the size of about 120,000 asteroids in the main belt, including 1056 members of the Baptistina family. The scientists calculated the original parent Baptistina asteroid actually broke up closer to 80 million years ago, half as long as originally proposed.

This calculation was possible because the size and reflectivity of the asteroid family members indicate how much time would have been required to reach their current locations — larger asteroids would not disperse in their orbits as fast as smaller ones. The results revealed a chunk of the original Baptistina asteroid needed to hit Earth in less time than previously believed, in just about 15 million years, to cause the extinction of the dinosaurs.

"This doesn't give the remnants from the collision very much time to move into a resonance spot, and get flung down to Earth 65 million years ago," said Amy Mainzer, a study co-author and the principal investigator of NEOWISE at NASA's Jet Propulsion Laboratory. "This process is thought to normally take many tens of millions of years." Resonances are areas in the main belt where gravity nudges from Jupiter and Saturn can act like a pinball machine to fling asteroids out of the main belt and into the region near Earth.

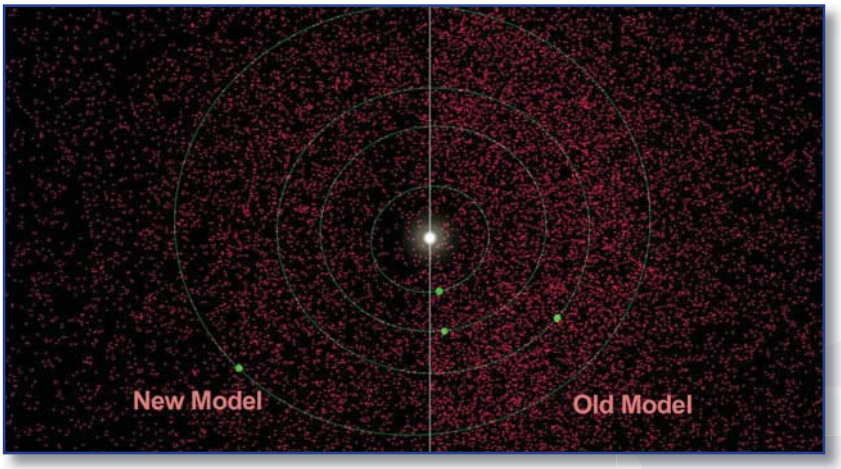
For more information, visit *www.nasa.gov/wise*, *wise.astro.ucla.edu*, or *jpl.nasa.gov/wise*.

NASA Space Telescope Finds Fewer Asteroids Near Earth

New observations by NASA's Wide-field Infrared Survey Explorer (WISE) show there are significantly fewer near-Earth asteroids in the mid-sized range than previously thought. The findings also indicate NASA has found more than 90% of the largest near-Earth asteroids, meeting a goal agreed to with Congress in 1998.

Astronomers now estimate there are roughly 19,500 — not 35,000 — mid-sized near-Earth asteroids. Scientists say this improved understanding of the population may indicate the hazard to Earth could be

somewhat less than previously thought. However, the majority of these mid-sized asteroids remain to be discovered. More research also is needed to determine if fewer mid-sized objects (between 330 and 3300 feet wide) also mean fewer potentially hazardous asteroids, those that come closest to Earth.



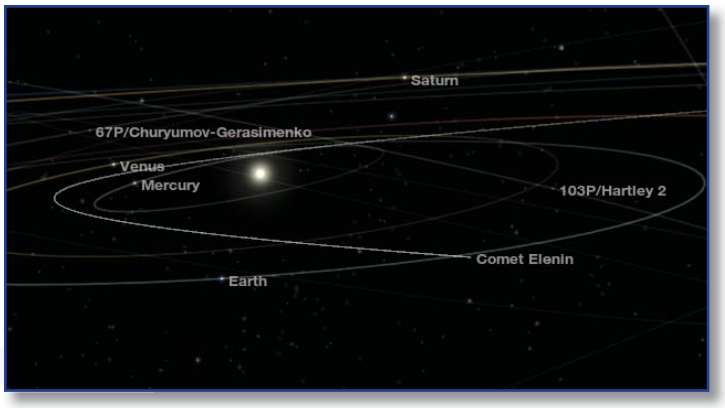
NEOWISE observations indicate that there are at least 40% fewer near-Earth asteroids in total that are larger than 330 feet (100 meters). Our solar system's four inner planets are shown in green, and our Sun is in the center. Each red dot represents one asteroid. Object sizes are not to scale. Credit: NASA/JPL-Caltech.

The results come from the most accurate census to date of near-Earth asteroids, the space rocks that orbit within 120 million miles (195 million kilometers) of the Sun into Earth's orbital vicinity. WISE observed infrared light from those in the mid- to large-sized category. The survey project, called NEOWISE, is the asteroid-hunting portion of the WISE mission. Study results appeared in *The Astrophysical Journal*.

"NEOWISE allowed us to take a look at a more representative slice of the near-Earth asteroid numbers and make better estimates about the whole population," said Amy Mainzer, lead author of the new study and principal investigator for the NEOWISE project at NASA's Jet Propulsion Laboratory. "It's like a population census, where you poll a small group of people to draw conclusions about the entire country." WISE captured a more accurate sample of the asteroid population than previous visible-light surveys because its infrared detectors could see both dark and light objects. It is difficult for visible-light telescopes to see the dim amounts of visible light reflected by dark asteroids. Infrared-sensing telescopes detect an object's heat, which is dependent on size and not reflective properties.

Although the WISE data reveal only a small decline in the estimated numbers for the largest near-Earth asteroids, which are 3300 feet (1 kilometer) and larger, they show 93% of the estimated population have been found. This fulfills the initial "Spaceguard" goal agreed to with Congress. These large asteroids are about the size of a small mountain and would have global consequences if they were to strike Earth. The new data revise their total numbers from about 1000 down to 981, of which 911 already have been found. None of them represents a threat to Earth in the next few centuries. It is believed that all near-Earth asteroids approximately 6 miles (10 kilometers) across, as big as the one thought to have wiped out the dinosaurs, have been found. "The risk of a really large asteroid impacting the Earth before we could find and warn of it has been substantially reduced," said Tim Spahr, the director of the Minor Planet Center at the Harvard Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

The situation is different for the mid-sized asteroids, which could destroy a metropolitan area if they were to impact in the wrong place. The NEOWISE results find a larger decline in the estimated population for these bodies than what was observed for the largest asteroids. So far, the Spaceguard effort has found and is tracking more than 5200 near-Earth asteroids 330 feet or larger, leaving more than an estimated 15,000 still to discover. In addition, scientists estimate there are more than a million unknown smaller near-Earth asteroids that could cause damage if they were to impact Earth.



Trajectory of Comet Elenin. Credit: NASA/JPL-Caltech.

Comet Elenin Gone and Should Be Forgotten

Comet Elenin is no more. Latest indications are this relatively small comet broke into even smaller, even less significant, chunks of dust and ice. This trail of piffling particles will remain on the same path as the original comet, completing its unexceptional swing through the inner solar system this past fall.

"Elenin did as new comets passing close by the Sun do about 2% of the time: It broke apart," said Don Yeomans of NASA's Near-Earth Object Program Office in Pasadena, California. "Elenin's remnants will also act as other broken-up comets act. They will trail along in a debris cloud that will follow a well-understood path out of the inner solar system. After that, we won't see the scraps of Comet Elenin around these parts for almost 12 millennia."

Twelve millennia may be a long time to Earthlings, but for those frozen inhabitants of the outer solar system who make this commute, a dozen millennia give or take is a walk in the celestial park. Comet Elenin came as close as 45 million miles (72 million kilometers) to the Sun, but it arrived from the outer solar system's Oort cloud, which is so far away its outer edge is about one-third of the way to the nearest star other than our Sun.

For those broken up over the breakup of what was formerly about 1.2 miles (2 kilometers) of uninspiring dust and ice, remember what Yeomans said about comets coming close to the Sun — they fall apart about 2% of the time.

"Comets are made up of ice, rock, dust, and organic compounds and can be several miles in diameter, but they are fragile and loosely held together like dust balls," said Yeomans. "So it doesn't take much to get a comet to disintegrate, and with comets, once they break up, there is no hope of reconciliation."

Comet Elenin first came to light last December, when sunlight reflecting off the small comet was detected by Russian astronomer Leonid Elenin of Lyubertsy, Russia. Also known by its astronomical name, C/2010 X1, Elenin somehow quickly became something of a "cause célèbre" for a few Internet bloggers, who proclaimed this minor comet could/would/should be responsible for causing any number of disasters to befall our planet. Internet posts began appearing, many with nebulous, hearsay observations and speculations about earthquakes and other disasters being due to Elenin's gravitational effects upon Earth. NASA's response to such wild speculations was then in turn speculated to be an attempt to hide the truth.

"I cannot begin to guess why this little comet became such a big Internet sensation," said Yeomans. "The scientific reality is this modest-sized icy dirtball's influence upon our planet is so incredibly miniscule that my subcompact automobile exerts a greater gravitational influence on Earth than the comet ever would. That includes the date it came closest to Earth (October 16), when the comet's remnants got no closer than about 22 million miles (35.4 million kilometers)."

Yeomans knows that while Elenin may be gone, there will always be Internet rumors that will attempt to conjure up some form of interplanetary bogeyman out of Elenin, or some equally obscure and scientifically uninteresting near-Earth object. Thinking of ways to make himself any more clear about the insignificance of this matter is somewhat challenging for a scientist who has dedicated his life to observing asteroids and comets and discovering their true nature and effects on our solar system.

"Perhaps a little homage to a classic Monty Python dead parrot sketch is in order," said Yeomans. "Comet Elenin has rung down the curtain and joined the choir invisible. This is an ex-comet."

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

Caltech-Led Team of Astronomers Finds 18 New Planets

Discoveries of new planets just keep coming and coming. Take, for instance, the 18 recently found by a team of astronomers led by scientists at the California Institute of Technology (Caltech). "It's the largest single announcement of planets in orbit around stars more massive than the Sun, aside from the discoveries made by the Kepler mission," says John Johnson, assistant professor of astronomy at Caltech and the first author on the team's paper, which was published in the December issue of *The Astrophysical Journal Supplement Series*. The Kepler mission is a space telescope that has so far identified more than 1200 possible planets, although the majority of those have not yet been confirmed.

The twin telescopes at Keck Observatory in Hawaii. A team led by scientists at Caltech used Keck to discover 18 new Jupiter-like planets orbiting massive stars. Credit: Rick Peterson/ W. M. Keck Observatory.

Using the Keck Observatory in Hawaii — with follow-up observations using the McDonald and Fairborn Observatories in Texas and Arizona, respectively — the researchers surveyed about 300 stars. They focused on those dubbed "retired" A-type stars that are more than one-and-a-half times more massive than the Sun. These stars are just past the main stage of their life — hence, "retired" — and are now puffing up into what's called a subgiant star.

To look for planets, the astronomers searched for stars of this type that wobble, which could be caused by the gravitational tug of an orbiting planet. By searching the wobbly stars' spectra for Doppler shifts — the lengthening and contracting of wavelengths due to motion away from and toward the observer — the team found 18 planets with masses similar to Jupiter's. This new bounty marks a 50% increase in the number of known planets orbiting massive stars and, according to Johnson, provides an invaluable population of planetary systems for understanding how planets — and our own solar system — might form. The researchers say that the findings also lend further support to the theory that planets grow from seed particles that accumulate gas and dust in a disk surrounding a newborn star.

According to this theory, tiny particles start to clump together, eventually snowballing into a planet. If this is the true sequence of events, the characteristics of the resulting planetary system — such as the number and size of the planets, or their orbital shapes — will depend on the mass of the star. For instance, a more massive star would mean a bigger disk, which in turn would mean more material to produce a greater number of giant planets. In another theory, planets form when large amounts of gas and dust in the disk spontaneously collapse into big, dense clumps that then become planets. But in this picture, it turns out that the mass of the star doesn't affect the kinds of planets that are produced.

So far, as the number of discovered planets has grown, astronomers are finding that stellar mass does seem to be important in determining the prevalence of giant planets. The newly discovered planets further support this pattern — and are therefore consistent with the first theory, the one stating that planets are born from seed particles.

"It's nice to see all these converging lines of evidence pointing toward one class of formation mechanisms," Johnson says. There's another interesting twist, he adds: "Not only do we find Jupiter-like planets more frequently around massive stars, but we find them in wider orbits." If you took a sample of 18 planets around Sun-like stars, he explains, half of them would orbit close to their stars. But in the cases of the new planets, all are farther away, at least 0.7 astronomical units from their stars. (One astronomical unit, or AU, is the distance from Earth to the Sun.)

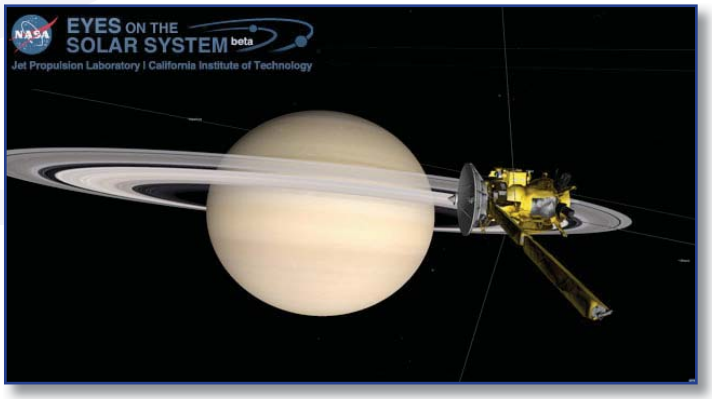
In systems with Sun-like stars, gas giants like Jupiter acquire close orbits when they migrate toward their stars. According to theories of planet formation, gas giants could only have formed far from their stars, where it's cold enough for their constituent gases and ices to exist. So for gas giants to orbit nearer to their stars, certain gravitational interactions have to take place to pull these planets in. Then, some other mechanism — perhaps the star's magnetic field — has to kick in to stop them from spiraling into a fiery death.

The question, Johnson says, is why this doesn't seem to happen with so-called hot Jupiters orbiting massive stars, and whether that dearth is due to nature or nurture. In the nature explanation, Jupiter-like planets that orbit massive stars just wouldn't ever migrate inward. In the nurture interpretation, the planets would move in, but there would be nothing to prevent them from plunging into their stars. Or perhaps the stars evolve and swell up, consuming their planets. Which is the case? According to Johnson, subgiants like the A stars they were looking at in this paper simply don't expand enough to gobble up hot Jupiters. So unless A stars have some unique characteristic that would prevent them from stopping migrating planets — such as a lack of a magnetic field early in their lives — it looks like the nature explanation is the more plausible one.

The new batch of planets have yet another interesting pattern: Their orbits are mainly circular, while planets around Sun-like stars span a wide range of circular to elliptical paths. Johnson says he's now trying to find an explanation. For Johnson, these discoveries have been a long time coming. This latest find, for instance, comes from an astronomical survey that he started while a graduate student; because these planets have wide orbits, they can take a couple of years to make a single revolution, meaning that it can also take quite a few years before their stars' periodic wobbles become apparent to an observer. Now, the discoveries are finally coming in. "I liken it to a garden — you plant the seeds and put a lot of work into it," he says. "Then, a decade in, your garden is big and flourishing. That's where I am right now. My garden is full of these big, bright, juicy tomatoes — these Jupiter-sized planets."

NASA Gives Public New Internet Tool to Explore the Solar System

NASA is giving the public the power to journey through the solar system using a new interactive web-based tool. The "Eyes on the Solar System" interface combines video game technology and NASA data to create an environment for users to ride along with agency spacecraft and explore the cosmos. Screen graphics and information such as planet locations and spacecraft maneuvers use actual space mission data.



NASA's new web-based application, "Eyes on the Solar System," gives people the power to journey through the solar system without leaving their computers. Credit: NASA/JPL-Caltech.

"This is the first time the public has been able to see the entire solar system and our missions moving together in real time," said Jim Green, director of NASA's Planetary Science Division at NASA Headquarters in Washington, DC. "It demonstrates NASA's continued commitment to share our science with everyone."

The virtual environment uses the Unity game engine to display models of planets, moons, asteroids, comets, and spacecraft as they move through our solar system. With keyboard and mouse controls, users cruise through space to explore anything that catches their interest. A free browser plug-in, available at the site, is required to run the web application. Users may experience missions in real time, and "Eyes on the Solar System" also allows them to travel through time. The tool is populated with NASA data dating back to 1950 and projected to 2050.

The playback rate can be sped up or slowed down. When NASA's Juno spacecraft launched on August 5, 2011, users could look ahead to see the mission's five-year journey to Jupiter in a matter of seconds. Point of view can be switched from faraway to close-up to right "on board" the spacecraft. Location, motion, and appearance are based on predicted and reconstructed mission data. Dozens of controls on a series of pop-up menus allow users to fully customize what they see, and video and audio tutorials explain how to use the tool's many options. Users may choose from two-dimensional or three-dimensional modes, with the latter simply requiring a pair of red-cyan glasses to see.

"By basing our visualization primarily on mission data, this tool will help both NASA and the public better understand complex space science missions," said Kevin Hussey, manager of Visualization Technology Applications and Development at JPL, whose team developed "Eyes on the Solar System."

For more information, visit *solarsystem.nasa.gov/eyes/*.

LPI Summer Intern Program in Planetary Science

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

The 10-week program begins June 4, 2012, and ends on August 10, 2012. Selected students will receive a $5000.00 stipend plus a travel stipend of $1000.00 (U.S. students) (foreign nationals will receive a $1500.00 foreign travel reimbursement).

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

The deadline for applying for the 2012 program is **Friday, January 20, 2012**. For more information, including eligibility and selection criteria, areas of research, and an online application form, please visit *www.lpi.usra.edu/lpiintern*.

Lunar Exploration Summer Intern Program

The Lunar and Planetary Institute (LPI) is hosting a special summer intern program to evaluate possible landing sites for robotic and human exploration missions. The LPI invites applications from graduate students in geology, planetary science, and related programs. The program is also open to undergraduate students in geology, astronomy, chemistry, and physics with at least 50 semester hours of credit so that they, too, can participate in lunar exploration activities. The goal of this program is to integrate NASA's lunar science priorities with the exploration components of the new exploration program that takes us beyond low-Earth orbit. This will be a unique team activity that should foster extensive discussions among students and senior science team members.

The 10-week program runs from May 29, 2012, through August 3, 2012. Selected interns will receive a $5000.00 stipend to cover the costs associated with being in Houston for the duration of the program. Additionally, U.S. citizens will receive up to $1000.00 in travel expense reimbursement, and foreign nationals will receive up to $1500.00 in travel expense reimbursement.

The application deadline for the 2012 program is **Friday, January 20, 2012**. For more information, or to access the electronic application form, visit *www.lpi.usra.edu/lunar_intern*.

Graduate Students Eligible for the LPI Career Development Award

Career Development Award

The Lunar and Planetary Institute (LPI) is proud to announce its fifth LPI Career Development Award, which is open to both U.S. and non-U.S. applicants. This award will be given to graduate students who have submitted a first-author abstract for presentation at the 43rd Lunar and Planetary Science Conference (LPSC). A travel stipend of $1000.00 will be awarded to the top applicants to help cover travel expenses for attending the LPSC in March.

The application deadline for the LPI Career Development Award is **January 13, 2012**. Applications should be directed to Dr. Stephen Mackwell, c/o Claudia Quintana, 3600 Bay Area Boulevard, Houston TX 77058-1113 (*cquintana@hou.usra.edu*).

Awards will be based on a review of the application materials by a panel of lunar and planetary scientists. Applications must include (1) a letter outlining why the applicant would like to participate at the LPSC and what he or she will contribute to the conference; (2) a letter of recommendation from his or her research advisor; (3) a copy of the first-author abstract; and (4) a Curriculum Vita for the applicant.

The 43rd LPSC will be held at The Woodlands Waterway Marriott Hotel & Convention Center in The Woodlands, Texas. More than 2000 participants from all over the world are expected to gather for the annual meeting, which has gained the reputation of being the premiere gathering place for lunar and planetary scientists. For more information about the conference, visit *www.lpi.usra.edu/meetings/lpsc2012/*.

NASA's Planetary Science Summer School

NASA's 24th Annual Planetary Science Summer School, held at the Jet Propulsion Laboratory, seeks applicants who have completed their graduate work and beyond in science and engineering fields, and who have a keen interest in a career in planetary exploration. Preference is given to post-docs, recent Ph.D.s, and current doctoral students; applications from masters'-level students or faculty members will be considered on a space-available basis. Applicants must be living within the U.S. at the time of the application. Preference will be given to U.S. citizens and U.S. legal permanent residents ("green card" holders).

Session 1 will be held from June 18–22, and session 2 will be held from July 16–20. Only 18 students can be accommodated in each session, and the deadline for application is March 28, 2012. Further information is available at *pscischool.jpl.nasa.gov*.

Texas Community College Aerospace Scholars

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

The application deadline is **February 10, 2012**. For more information, visit *cas.aerospacescholars.org*.

NASA's Planetary Geology and Geophysics Undergraduate Research Program (PGGURP)

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

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

The application deadline is **January 30, 2012**. For more information, visit *www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships (SURF)

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

The deadline for all application materials is **February 22, 2012**. For more information, visit *www.surf.caltech.edu*.

Research Experiences for Undergraduates (REU) Program, American Museum of Natural History

AMERICAN MUSEUM of NATURAL HISTORY

The AMNH Division of Physical Sciences, in collaboration with the City University of New York (CUNY), is pleased to offer summer research opportunities in astrophysics and Earth and planetary science. The program is open to all students who are U. S. citizens or permanent residents in any four-year undergraduate degree program. Pending the approval of federal funding, successful applicants will receive a stipend of at least $4000.00. In addition, dormitory housing on a nearby university campus, or an equivalent housing stipend, will be provided together with a subsistence allowance. Based on need, travel costs to and from New York City are also covered.

The application deadline is **February 1, 2012**. For more information, visit *research.amnh.org/physsci/reu2004.html*.

SAO Summer Intern Program

The Smithsonian Astrophysical Observatory (SAO) Summer Intern Program is a Research Experiences for Undergraduates (REU) program where students work on astrophysics research with an SAO/Harvard scientist. In 2012 the program is expected to run 10 weeks, from June 10 through August 17, contingent on the availability of housing. Students are expected to be in residence at the Harvard-Smithsonian Center for Astrophysics (CfA) for the full duration of the program.

The program is funded by the National Science Foundation and the Smithsonian Institution. Undergraduate students interested in a career in astronomy, astrophysics, physics, or related

physical sciences are encouraged to apply. Applicants must be U.S. citizens or permanent residents ("green card" holders), and must be enrolled in a degree program leading to a bachelors" degree. Seniors who will graduate in June of 2012 (or before) are not eligible.

The application deadline is **February 1, 2012**. For more information, visit *hea-www.harvard.edu/REU/REU.html*.

NASA Minority Innovation Challenges Institute

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

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

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

NASA Wants Student Innovators for 2011 Great Moonbuggy Race

The 19th Annual Great Moonbuggy Race will be held April 13–14, 2012, in Huntsville, Alabama, at the U.S. Space & Rocket Center. Students are required to design a vehicle that addresses a series of engineering problems that are similar to problems faced by the original Moonbuggy team. Each Moonbuggy will be human powered and carry two students, one female and one male, over a half-mile simulated lunar terrain course including "craters," rocks, "lava" ridges, inclines, and "lunar" soil.

Moonbuggy entries are expected to be of "proof-of-concept" and engineering test model nature, rather than final production models. Each student team of six members is responsible for building their own buggy, and the course drivers, who are chosen from each team, must also be builders

of the vehicle. U.S. registration closes on **February 10, 2012**, and international registration ends on **January 9, 2012**. For complete rules, vehicle design parameters, and registration for the race, visit *moonbuggy.msfc.nasa.gov*.

NASA Academies for College Students

The Academies are intensive educational programs that emphasize group activities, teamwork, research, leadership, and creativity. The curriculum balances direct contact with science and engineering research and development with an awareness of the managerial, political, financial, social, and human issues faced by aerospace professionals. Included are seminars, informal discussions, evening lectures, supervised research, visits to other NASA Centers and facilities, group projects, tours, posters/presentations, and assessment. Additionally, most weekends are filled with group activities, team building, and offsite trips. One free weekend is scheduled.

The Academy is not a 9 to 5 summer research internship program. It is a rigorous, immersive experience that will challenge you and push you outside your comfort zones. It offers participants an intense learning experience that is either space- or aeronautics-based. All Academy students will be immersed in a NASA environment where they will experience the agency from both inside and outside perspectives. Additionally, added interaction with NASA collaborators in industry and academia will provide a unique, exciting, and unforgettable summer experience designed to engage and capture students within the NASA family.

Eligibility requirements differ for each Academy. Applications are due **January 23, 2012**. For more information and to apply online, visit *https://www.academyapp.com/*.

NASA's DEVELOP Program

DEVELOP is a NASA Science Mission Directorate Applied Sciences-sponsored internship that fosters the training and development of students in the atmospheric and Earth sciences. The DEVELOP program extends the application of NASA Earth science research and technology to meet societal needs. Students conduct projects that focus on the practical application of NASA's Earth science research and demonstrate how results can benefit partner organizations and local communities. Advisors and mentors, from NASA and partner institutions, provide guidance and support for the program. Students gain experience using NASA science and technology in a professional setting.

Students from high school through doctoral levels are selected through a competitive application process. Students chosen by DEVELOP work on teams onsite at 10 locations nationwide. Activities are conducted during three 10-week terms per year: spring, summer and fall. To apply to a DEVELOP center at a NASA location, applicants must be a citizen of the U.S. However,

international students currently registered at an accredited school in the U.S. are eligible to apply to DEVELOP regional locations. International applicants must already have a visa that permits them to work in the U.S.

Applications for the summer 2012 session are due **January 30, 2012**. For more information about this unique internship opportunity, please visit the DEVELOP website at *develop.larc.nasa.gov*. Questions about the DEVELOP program should be directed to *NASA-DL-DEVELOP@mail.nasa.gov* or 757-864-3761.

Are You the Next Carl Sagan? Come Find Out at FameLab Astrobiology!

Calling all graduate students and postdocs doing research related to astrobiology . . . FameLab Astrobiology is a science communication extravaganza! Via four preliminaries and one final competition — spanning January thru April 2012 — early career astrobiologists will compete to convey their own research or related science concepts. Each contestant has the spotlight for only three minutes . . . no slides, no charts — just the power of words and anything you can hold in your hands. A panel of experts in both science and science communication will do the judging. One of the four preliminaries will be held 100% online via YouTube!

Beyond the competition, at each preliminary event there will be science communication training and enrichment activities, providing exposure to alternative careers. There will also be a two-day master class for finalists just prior to the Astrobiology Science Conference in April 2012. Other science communication opportunities will be available, including joining a network of other FameLab participants from around the globe. The winner goes on to compete in the International FameLab Final in the United Kingdom in June 2012.

The first preliminary round will be held at the Lunar and Planetary Institute in Houston on January 13. Information about other locations, as well as registration, eligibility requirements, and more can be found at *astrobiologyfamelab.arc.nasa.gov/*. Questions can be directed to Daniella Scalice at the NASA Astrobiology Institute at *daniella.m.scalice@nasa.gov*.

2012 NASA Student Airborne Research Program

The NASA Airborne Science Program invites highly motivated junior and senior undergraduate and early graduate students to apply for the NASA Student Airborne Research Program (SARP). The program provides students with hands-on research experience in all aspects of a major scientific campaign, from detailed planning on how to achieve mission objectives to formal presentation of results and conclusions to peers and others. Students will assist in the operation of airborne instruments onboard the NASA P-3 aircraft. The program takes place in summer 2012. Preparatory information and data analysis will take place at the University of California, Irvine. Instrument and flight preparations, and the research flights themselves, will occur at NASA's Dryden Aircraft Operations Facility in Palmdale, California.

Successful applicants will be awarded a $3000.00 stipend and $2500.00 meals allowance for eight weeks of participation in the program. Round-trip travel to California, housing, and transportation will be provided. Applications received by January 20, 2012, will be considered for early acceptance. The deadline for all applications is **February 10, 2012**. For more information and to download the program application, visit *www.nserc.und.edu/learning/SARP2012.html*.

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

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

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

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

Copy deadline for the next issue: January 15, 2012

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

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

Continuing the Year of the Solar System (YSS)

Spanning a martian year — 23 months — the Year of the Solar System celebrates the amazing discoveries of numerous NASA missions as they explore our near and distant neighbors and probe the very outer edges of our solar system. Each month, from October 2010 to August 2012, audiences explore different aspects or our solar system — its formation, volcanism, ice, life — weaving together activities, resources, and ideas that teachers, clubs, and organizations can use to engage audiences. Visit *solarsystem.nasa.gov/yss*.

The topic for November is Magnetospheres: Planetary Shields. Join us this month to investigate magnetic fields and planetary magnetospheres, through a variety of activities and mission resources. We will also celebrate the launch of the Mars Science Laboratory on its way to deliver the rover Curiosity to the surface of the Red Planet!

The December–January topic is Evolving Worlds, when we investigate how planets evolve. Jupiter AND Venus are bright in the evening sky and if you're lucky, you may catch a glimpse of some meteors from the Geminid or Quadrantid meteor showers!

The topic for February is Far-Ranging Robots; we will celebrate National Engineers Week, and explore the variety of robotic spacecraft in our solar system.

Get Involved! Share Your YSS Events and Stories: Advertise your YSS Events on the YSS Calendar. Share your YSS stories through the YSS story space, and Flickr and YouTube. Visit *solarsystem.nasa.gov/yss/getinvolved.cfm*.

Link to YSS from Your Website: We invite you be a YSS partner during the Year of the Solar System! Post the YSS graphic element on your website and link to the YSS page. You can find YSS graphics at *solarsystem.nasa.gov//yss/display.cfm?Year=2010&Month=12&Tab=Downloads*.

Ideas? Feedback? Contact us at *planetaryforum@lpi.usra.edu*.

LPSC Education and Public Outreach Events

Oral and Poster Abstracts

The 43rd Lunar and Planetary Science Conference (LPSC) will be held at The Woodlands Waterway Marriott Hotel and Convention Center, The Woodlands, Texas, March 19–23, 2012. Planetary science E/PO specialists are invited to submit abstracts to share their innovative programs, projects, and results.

This conference brings together international specialists in petrology, geochemistry, geophysics, geology, and astronomy to present the latest results of research in planetary science. The five-day conference will be organized by topical symposia and problem-oriented sessions.

The abstract deadline is **January 10, 2012**; abstracts can be submitted at the LPSC website at *www.lpi.usra.edu/meetings/lpsc2012/*.

Planetary Undergraduate Faculty Workshop

Sunday, March 18, 1:00 p.m. to 5:00 p.m.

Save the date! The Third Planetary Undergraduate Faculty Workshop will be held Sunday afternoon, March 18, from 1:00 to 5:00 p.m. at the LPSC venue. The topic of the workshop is to be decided — if you have an idea for a workshop that you would like to have considered, please let us know! RVSP interest to Dr. Emily CoBabe-Ammann at *ecobabe@spaceeducation.org*.

Undergraduate Planetary Science Research Conference

Sunday, March 18, 9:00 a.m. to 5:00 p.m., Town Hall Exhibit Center

As part of the NASA SMD Year of the Solar System (YSS), an Undergraduate Planetary Science Research Conference is being hosted in conjunction with LPSC.

The Undergraduate Planetary Science Research Conference includes:

- Panels on “How to Choose the Grad School Right for You,” “Alternative Careers in Science,” and “Women in Planetary Science”
- Poster sessions where students will present their posters to other student and to the scientific community
- “Meeting Mentors,” which will pair students with a scientist for part of the LPSC meeting, so students can learn how to engage at a scientific conference
- Opportunities to meet other undergraduate researchers, graduate students, and scientists

Undergraduate students currently conducting research in planetary sciences, astrobiology, and lunar sciences are eligible. To learn more and to apply, please visit *www.lpi.usra.edu/meetings/lpsc2012/events/education/*. Applications are due by close of business February 10, 2012.

Some travel support will be available to students who qualify. Priority will be given to students of diverse backgrounds. Students are encouraged to attend LPSC and the travel support includes registration for and participation in LPSC. For additional information, please contact Dr. Emily CoBabe-Ammann at *ecobabe@spaceeducation.org*.

"Descubrimientos En Ciencias Planetarias": Classroom Powerpoints Available In Spanish

The Division for Planetary Sciences announces the release of "Descubrimientos en Ciencias Planetarias," the Spanish translation of the "DPS Discoveries" Classroom Powerpoints. These classroom slidesets are succinct summaries of discoveries too recent to appear in "Intro Astronomy" college textbooks; each set consists of just three slides to be shown: the discovery itself, a basic explanation based on good planetary science, and the "big picture" context. Another page for further information is provided as well. Powerpoints and PDFs can be downloaded from *dps.aas.org/education/dpsdisc*, which has links to the Spanish and English versions.

For more information, contact Nick Schneider and Dave Brain at *dpsdisc@aas.org*.

Awards For Excellence in Astronomy Education

The Astronomical Society of the Pacific is now accepting nominations for the Society's 2012 awards honoring accomplishments in astronomy education and public outreach. Recipients receive a cash award and engraved plaque, as well as travel and lodging to accept the award at the Society's 2012 Meeting next summer.

- The Richard Emmons Award celebrates a lifetime of outstanding achievement in the teaching of college-level introductory astronomy for non-science majors.
- The Klumpke-Roberts Award recognizes those who have made major contributions to the public understanding and appreciation of astronomy.
- The Thomas J. Brennan Award is given for excellence in the teaching of astronomy at the high school level in North America.
- The Las Cumbres Amateur Outreach Award honors outstanding educational outreach by an amateur astronomer to K–12 students and the public.

Submission guidelines and lists of past recipients can be found at *www.astrosociety.org/membership/awards/awards.html*. The deadline for nominations is December 15, 2011. You do not need to be a member of the Society to make or second a nomination. If you have questions or need additional information, please contact Albert Silva at *asilva@astrosociety.org* or 415-337-1100 ext. 100.

365 Days of Astronomy Needs You!

The 365 Days of Astronomy podcast launched as the official podcast of the 2009 International Year of Astronomy. Designed with the mission of providing a place for people to share their passion for astronomy and space science, this Parsec-award-winning audio show has told the stories of professional astronomers, children, amateur astronomers, artists, poets, and science fiction writers from six continents. On September 27, 2011, the show ran its 1000th episode! The EPO community and scientists are invited to submit new episodes, to ask their team to produce episodes, and to donate funding, at *365daysofastronomy.org/join-in/*. Spread the word about your programs and research with 365 Days of Astronomy!

Young Naturalist Awards

The American Museum of Natural History Young Naturalist Awards invites students in grades 7–12 to participate in a research-based essay contest to promote participation and communication in science. Two winners from each grade level will be selected to receive cash scholarship awards, and the teachers of the top 12 winners will receive resources for their classroom. Children are asked to conduct their own scientific expedition in astronomy, Earth science, or biology. The expedition will provide original data, questions, and observations. The expedition should provide the child with a new understanding about the question that was investigated. The essay about the expedition should contain artwork and/or photographs that help to illustrate the findings. Connect with a local teacher and become a mentor for interested students!

The deadline for the contest is March 9, 2012. Winning essays will be published on the American Museum of Natural History website the week of March 19, 2012. For more information, contact Christine Economos, Young Naturalist Awards administrator, at *yna@amnh.org* or call 212-496-3498 or visit *www.amnh.org/nationalcenter/youngnaturalistawards/*.

Sun-Earth Day

Sun-Earth Day is comprised of a series of programs and events that occur throughout the year culminating with a celebration on or near the spring equinox; in 2012, the annual celebration will be March 19. The focus in 2012, however, will be on the upcoming June 5, 2012, transit of Venus, which will be visible on June 5 or 6, depending on your location. Check out the site for educational programs, activities, resources, and more, and plan your own Sun-Earth Day celebration! Visit *sunearthday.nasa.gov/2012/about/about.php*.

Ronald Greeley, 1939–2011

Ronald Greeley, a Regents' Professor of Planetary Geology at Arizona State University (ASU), died on October 27, 2011, in Tempe, Arizona. He was 72 years old.

The son of a military serviceman, Greeley moved around a great deal as child. As a result, he saw many different geological landforms, and it was no surprise that when he went to college, he majored in geology. Greeley earned undergraduate and graduate degrees from Mississippi State University. After receiving his doctorate in 1966 at the University of Missouri in Rolla he worked for Standard Oil Company of California as a paleontologist. Through military duty, he was assigned to NASA's Ames Research Center in 1967, where he worked in a civilian capacity in preparation for the Apollo missions to the Moon. He stayed on at NASA to conduct research in planetary geology.

Greeley began teaching at ASU in 1977 with a joint professorship in the department of geology and the Center for Meteorite Studies. He studied wind processes on Earth and other planets and conducted photogeological mapping of planets and satellites, among other research projects. In 1986, Greeley left the Center for Meteorite Studies to serve as chair of the department of geology.

"Ron Greeley was indisputably one of the founders of planetary science, and the influence he has had, both through his own work and through the students and colleagues that he guided and mentored, touches virtually all aspects of this field," says Phil Christensen, a Regents' Professor in the School of Earth and Space Exploration in ASU's College of Liberal Arts and Sciences.

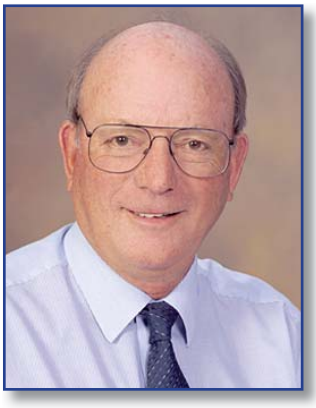
Greeley, a pioneer in the planetary geology field, served as the director of the NASA-ASU Regional Planetary Image Facility and principal investigator of the Planetary Aeolian Laboratory at NASA-Ames Research Center. He served on and chaired many NASA and National Academy of Science panels and he was involved in nearly every major space probe mission flown in the solar system since the Apollo Moon landing. Mission projects included the Galileo mission to Jupiter, Magellan mission to Venus, and Shuttle Imaging Radar orbiter around Earth. He was also part of the data analysis program for the Voyager 2 mission to Uranus and Neptune. His projects focused on the moons of these distant bodies. Passionate about Mars exploration, he was also involved with several missions to the Red Planet, including Mariner (6, 7, 9), Viking, Mars Pathfinder, Mars Global Surveyor, and the Mars Exploration Rovers. He was also a co-investigator for the camera system onboard the European Mars Express mission.

Former students scattered throughout the universities and research institutes of this country provide testimony to his influence on planetary geology.

"As I began my research career, Ron reminded me of the old adage: 'A journey of 1000 miles begins with a single step.' I am fortunate to have had Ron there walking beside me," says Robert Pappalardo, senior research scientist at NASA's Jet Propulsion Laboratory. Greeley served as Pappalardo's advisor. After receiving his doctorate from ASU in 1994, Pappalardo worked with Greeley for one year immediately after that as a postdoc. Since about 2002, the two had worked together on the science basis for Europa mission studies. "Ron was a gentleman, a statesman, a mentor, a scholar," says Pappalardo. "Not a day goes by that I don't think, in some situation, 'What would Ron Greeley do?'"

Greeley's work lives on in proposed missions to Europa, a moon of Jupiter, and in the numerous students he mentored who today play pivotal roles in space science efforts.

— Text courtesy of Arizona State University



Michael J. Drake, 1946–2011

Michael J. Drake, Regents' Professor, Director of the University of Arizona's (UA) Lunar and Planetary Laboratory (LPL), and head of the Department of Planetary Sciences, died September 21, 2011, at The University of Arizona Medical Center–University Campus in Tucson, Arizona. He was 65.

Drake, who joined the UA planetary sciences faculty in 1973 and headed LPL and the planetary sciences department since 1994, was the principal investigator of the most ambitious UA project to date, OSIRIS-REx, an $800 million mission designed to retrieve a sample of an asteroid and return it to Earth. OSIRIS-REx is due to launch in 2016.

Under Drake's leadership, the LPL grew from a small group of geologists and astronomers into an international powerhouse of research into the solar system. Drake played a key role in a succession of ever more high-profile space projects that garnered international attention for LPL and the university. Those include the Cassini mission to explore Saturn, the Gamma-Ray Spectrometer onboard NASA's Mars Odyssey Orbiter, the HiRISE camera onboard NASA's Mars Reconnaissance Orbiter, and the Phoenix Mars Lander. Drake also was a Fellow of the American Geophysical Union, the Geochemical Society, and the Meteoritical Society, and he was president of the latter two.

A native of Bristol, England, Drake graduated with a degree in geology from Victoria University in Manchester, and then he left for a doctoral program in geology from the University of Oregon, graduating in 1972. After a postdoctoral program at the Smithsonian Astrophysical Observatory, Drake moved to, and immediately fell in love with, Arizona. As a young assistant professor, Drake joined a much smaller LPL in 1973. The lab occupied only a part of what is now the Kuiper Space Sciences Building, and most of his colleagues came from astronomy. Planetary sciences did not have the cachet then that it does now. "It was, from my point of view, a strange environment," Drake wrote earlier on LPL's website. "It's like the Tower of Babel; you talk in your own language and your own jargon, and communicating across fields is surprisingly difficult. It took a few years before I think most of us began to understand what motivated the other ones, what we were really saying. I think it helped us to speak in clearer, plain English and minimize the jargon, because we came from such different backgrounds."

Regents' Professor Peter Strittmatter, who recently retired as director of the UA's Steward Observatory and head of the UA astronomy department, said Drake used those communication skills to expand LPL and form close relationships with NASA. "Mike thought and spoke clearly so you always knew where he stood on an issue," Strittmatter said. "He was a superb director of LPL, a great leader and a great personal friend. He will be sorely missed by all of us at the University of Arizona and especially those involved in the space sciences." Added Timothy Swindle, assistant director of LPL, "Not only was he a world-class scientist, but he was a tireless advocate for the Lunar and Planetary Laboratory and all the people who have worked here. Personally, he was a friend and mentor for me, and for many others, and we will miss him deeply."

— Text courtesy of The University of Arizona

Charles P. "Chuck" Sonett, 1924—2011

On September 30, 2011, Charles P. "Chuck" Sonett, Regents' Professor of Planetary Sciences Emeritus at The University of Arizona, died from complications of Parkinson's disease. Sonett was born January 15, 1924, in Pittsburgh, Pennsylvania, of Hungarian parents. When Sonett was young his family moved to the desert town of Trona, California, some 40 miles from Death Valley. There he became interested in geology and astronomy. He attended Hollywood High School in Los Angeles, where his interest in astronomy led him to telescope construction projects, including the figuring of mirror optics. As a youth he joined the Los Angeles Amateur Astronomical Society, and while in high school began construction of a 10-inch aperture telescope. He was also active in his high school Reserve Officers Training Corps program, rising to the rank of cadet corporal.

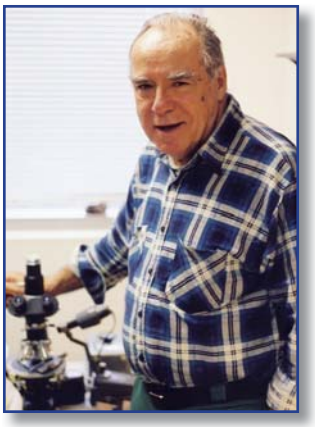
After graduation from high school, Sonett entered the University of California, Los Angeles (UCLA), majoring in physics. The Japanese bombing of Pearl Harbor in 1941 interrupted his studies. He enlisted in the Army on October 1942, finished his second year at UCLA, and entered active duty in May 1943. In March 1945, while on combat patrol in France, Sonett stepped on a German mine. His wounds required a battlefield amputation of his left leg. Sonett's military decorations included the Combat Infantryman's Badge, Bronze Star, and Purple Heart. After leaving the service, Sonett returned to UCLA to continue undergraduate work in physics. He then transferred to the University of California at Berkeley where he graduated in 1948. His first employment was with the Naval Radiological Defense Laboratory at Hunters Point, San Francisco, working in satellite planning. After one year he returned to UCLA where he received his Master of Arts in 1951 and Doctorate in 1954.

Following his graduation, Sonett's interest shifted from nuclear physics to rocketry and its application to exploration of the solar system. This change in interest coincided with the launch of Sputnik and the beginning of the "Space Race." Sonett began employment with Ramo-Wooldridge Corporation, Space Technology Laboratories division. Sonett was subsequently employed at NASA Headquarters in Washington, DC, where from 1960 to 1962 he was NASA's Chief of Sciences, Lunar and Planetary Programs. In 1962 Sonett became the head of the Space Sciences Division at NASA Ames Research Center. He remained at Ames for 11 years.

In 1969 Sonett received NASA's Exceptional Scientific Achievement Medal for unusually significant scientific contribution toward achievement of aeronautical or space exploration goals. In 1973, Gerard Kuiper, widely considered to be the father of modern planetary astronomy, invited Sonett to be his successor as director of The University of Arizona's Lunar and Planetary Laboratory (LPL), and to head the new interdisciplinary Department of Planetary Sciences, chartered that year by the Arizona Board of Regents. During his term as the second LPL director and first Planetary Sciences head, Sonett presided over a dramatic expansion. He built research and education programs in solar system science that became internationally recognized.

As a space exploration pioneer, Sonett was involved in the Pioneer, Explorer, Apollo, and Ulysses Programs. He was Principal Investigator on the Pioneer 1 Ion Chamber and Single Axis Search-Coil Magnetometer, Explorer 35 Ames Magnetic Fields Explorer, and Apollo 12 Lunar Surface Magnetometer. During the post-Apollo era, Sonett played an important role in efforts to understand the Moon's interior through the use of magnetic field measurements at the Moon's surface and from orbit. The culmination of his work at the University of Arizona during the late 1970s and early 1980s led to a firm upper bound of about 400 km for the radius of a highly electrically conducting metallic core in the Moon, proving a major dissimilarity of the Moon to Earth. Sonett's result is consistent with current estimates for the lunar core radius (about 330 to 350 km based on a variety of geophysical measurements).

— Text courtesy of the University of Arizona

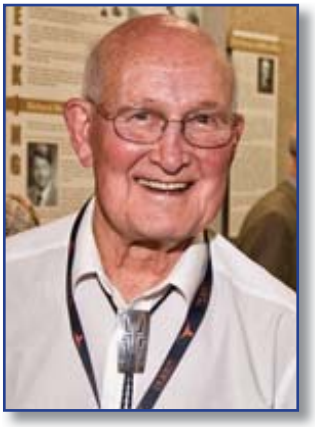


Paul Lowman, 1931–2011

Paul Lowman of the NASA Goddard Space Flight Center died on September 29, 2011, at the age of 80. Born in 1931, Lowman was one of the original scientists at Goddard. He spent several years with the U.S. Army Ordinance Corps, then as a field assistant at the U.S. Geological Survey before becoming, in 1959, "the first geologist hired by NASA." His early work at Goddard was in the Theoretical Division, then run by Robert Jastrow, where he worked with John O'Keefe on the origin of tektites and pre-Apollo lunar geology.

Lowman was closely tied to the Apollo program, helping to plan the early missions while detailed to NASA Headquarters, and later being involved in the analysis of lunar samples and the interpretation of Apollo 15 and 16 X-ray fluorescence and gamma-ray data. He was a Co-I on the IRIS experiment on the Mariner 9 mission to Mars. Long before it was a popular concept, Lowman was actually doing "comparative planetology," asking what the new information from the Moon and Mars could tell us about the Earth. He was the father of Earth orbital photography, having initiated that effort for early Mercury and Gemini missions. This led eventually to multispectral imaging of the Earth and the Landsat series of satellites.

Lowman's field work included studies of ancient exposed rocks in Scotland and the well-known Sudbury Crater in Ontario. In 2010, he returned to Sudbury Crater as the leader for a Goddard Lunar and Planetary Academy summer intern group. Lowman won the Lindsay Award in 1974 and the NASA Medal for Exceptional Service in 2003. He was author of several books on orbital photography of the Moon and Earth, and was on a first-name basis with many Apollo and Skylab astronauts, including John Young, Harrison "Jack" Schmitt, Owen Garriott, and Neil Armstrong. Armstrong wrote the foreword to Lowman's last book, *Exploring Space, Exploring Earth*, which was published by Cambridge University Press in 2002. That book describes the prominent role Goddard played in space exploration, something Lowman both witnessed and contributed to firsthand for more than 50 years. He will be greatly missed.



William R. Muehlberger, 1923–2011

William R. (Bill) Muehlberger died of natural causes on Wednesday, September 14, 2011, at the age of 87. Muehlberger was born in New York, New York, on September 26, 1923, and grew up in Hollywood, California. He entered the California Institute of Technology in 1941, but the U.S. Marine Corps sent him to the University of California (UC) at Berkeley in 1943 to study civil engineering. He remained at UC until 1944, one semester shy of a degree. He returned to the California Institute of Technology and completed his B.S. (1949), M.S. (1949), and Ph.D. (1954) degrees in structural geology.

Muehlberger joined the faculty at the University of Texas at Austin in 1954, where he taught structural geology and tectonics, and remained there until his retirement in 1992 when he became professor emeritus. He was director of the Crustal Studies Laboratory at the University of Texas from 1962 to 1966. He also served as chairman of the department from 1966 to 1970.

Muehlberger took a leave from the university from 1970 to 1973 to serve as NASA's Principal Investigator for Apollo 16 and 17, two missions in which astronauts carried out significant geological research. He continued as an instructor/advisor to the astronauts on Earth observations from Skylab, Apollo-Soyuz, the space shuttle, and the International Space Station. For his work over the years, he received the Medal for Exceptional Scientific Achievement and the Public Service Medal from NASA, as

well as the Houston Oil and Minerals Corporation Faculty Excellence Award. In 2009, he was inducted into the Jackson School's Hall of Distinction.

A structural geologist by trade, Muehlberger studied brittle fault zones and fracture systems worldwide. He also studied basement lineaments and correlated geophysical data with them. His work helped with the understanding of tectonics, focusing on the Western United States and Latin America. He compiled the most recent Tectonic Map of North America, grounded in plate tectonics concepts, and for that efforts was given the Outstanding Paper Award of the GSA Structure and Tectonics Division. With his extensive observations of the character of the Earth's crust, he was the ideal person to help assemble large-scale geological maps and to help educate NASA astronauts.

In 2010, a research symposium was organized in his honor, bringing together over 120 colleagues, friends and former students to share the fruits of their research in fields as diverse as North American tectonics, Central American and Caribbean geology, nuclear waste storage in Japan, natural resources, lunar geology, and human exploration of space. Speakers and attendees included two Apollo astronauts (Charles Duke and Harrison "Jack" Schmitt), three presidents of the Geological Society of America, three university deans, and representatives of state and federal government agencies, universities, petroleum and mining companies, and consulting firms. To ensure that his legacy endures, the William R. Muehlberger Graduate Fellowship in Structural Geology/Tectonics was established the same year to support "a graduate student possessing the greatest breadth and depth of geologic knowledge and who is focused on a research project aimed at resolving an important structural geology or tectonic problem." Within a few short months of establishing the fellowship, donors contributed the full $250,000 needed to fully fund the endowment.

— Text courtesy of the Austin American-Statesman and the Jackson School of Geosciences, University of Texas

Angioletta Coradini, 1946–2011

Angioletta Coradini, recognized as one of the world's leading experts in planetary science, passed away on September 4, 2011. Coradini's scientific interests ranged from minor bodies to outer planets, including theories about the formation of our solar system.

Coradini began her scientific career in 1969 with her Ph.D. thesis at the Rome University "La Sapienza" on the origin of glassy particles found in lunar soils. During the 1980s she collaborated with the team at NASA's Jet Propulsion Laboratory that developed the Thermal Infrared Mass Spectroscope (TIMS), gaining experience that allowed her to lead the Italian team for the Cassini VIMS Spectrometer visual channel. Coradini also provided management for a long series of successful space experiments, beginning with her PI-ship of the VIRTIS instrument onboard Rosetta, and including the VIR instrument on the Dawn mission, now in orbit around the asteroid Vesta. Other experiments in which Coradini was involved included JIRAM on the Juno mission en route to Jupiter, the infrared spectrometers on Venus Express and Bepi Colombo, and many other projects.

Coradini was Head of the Planetology Departement of the Istituto di Astrofisica Spaziale (1982–1986), Director of the CNR National Group of Astronomy (1984–1990), and Director of the CNR (after INAF) Istituto di Fisica dello Spazio Interplanetario (2003–2011). In recognition of her significant contributions to the planetary sciences she received many honors and awards. Angioletta will be deeply missed and remembered by her family, colleagues and friends.

Ronald N. Hartman, 1935–2011

Ronald N. Hartman passed away on August 30, 2011, after a brief illness. He was a Professor of Astronomy and Director of the Planetarium at Mt. San Antonio College in Walnut, California, for 38 years and was well known in the community of meteorite collectors and hunters. His passion for meteorites was kindled when he studied astronomy at the University of California, Los Angeles, under the renowned meteoriticist Frederick C. Leonard, a founder of the Meteoritical Society. He worked at Griffith Observatory giving public lectures in the 1960s and began investigating California dry lakes for the presence of meteorites. He discovered the Lucerne Dry Lake strewn field in 1963 and returned to that site in 1999 to find more of the elusive little black rocks from space. Throughout his career he continued to hunt for meteorites, first at Meteor Crater, Arizona (when it was still legal), and Odessa, Texas. He found, traded, bought, cut, and sold meteorites as well as tektites and shatter cones and built up a large collection, part of which is displayed at the Mt. San Antonio College Planetarium and library. In 2005 he founded R. N. Hartman, Inc., a company that manufactures, assembles, and distributes membrane suspension boxes worldwide.

Hartman held a B.A. in Astronomy and a B.A. in Cinematography from the University of California, Los Angeles, and an M.A. in Education from California State University at Los Angeles. He loved astronomy, teaching, and sharing the wonders of the night sky with his students at star parties, continuing to teach even after his retirement in 2005. Fascinated by archeoastronomy, he traveled to Egypt to study astronomical alignments in ancient monuments. He was active in the Pacific Planetarium Association and the International Planetarium Society, and served as an editor of Planetarian Magazine from 1978 to 1981. In 1984 he received the ISP Service Award, the ISP's most prestigious honor.

Andrew A. Dantzler, 1962–2011

Andrew Dantzler died unexpectedly on Thursday, October 13, 2011, at the age of 49. Dantzler worked at NASA from 1984 to 2006, serving as an optical engineer, Earth Observing System manager, Landsat 7 instrument manager, assistant chief of the Laboratory for High Energy Astrophysics, and Director of the Solar System Exploration Division at NASA Headquarters.

In 2006, Dantzler joined the Civilian Space Business Area at The Johns Hopkins University's Applied Physics Laboratory to lead the Living with a Star missions, which explore how the Sun's high-energy rays and energetic particles can generate hazardous space weather effects near the Earth and affect satellite operations, as well as the Earth's climate. He was also the first Program Manager for Solar Probe Plus, which will journey closer to the Sun than any probe has ever gone. Dantzler was promoted to Program Area Manager for Civilian Space in 2009, overseeing program management for projects such as the MESSENGER mission, now in orbit about Mercury, and the New Horizons mission, currently on its way to Pluto and the Kuiper belt. Besides science, Dantzler's other passion was Judo. He was a third-degree black belt in Judo and a member of the USA Judo Association, as well as a nationally certified coach and referee.

William H. Smyth, 1941–2011

William H. Smyth passed away on Friday, September 30, 2011, after a brief illness. He was 70 years old. Smyth graduated from Harvard in 1972, and after a postdoc appointment with Michael McElroy working on Voyager observations, he became an early staff member of AER (Atmospheric and Environmental Research) in Lexington, Massachusetts, where he spent almost all his professional career. Smyth was a leader in planetary exospheres and conducted pioneering research on the exospheres of Io, Europa, Mercury, the Moon, comets, and the saturnian H cloud, especially their complex orbital environments. His expertise on Io's neutral clouds and the plasma torus were second to none. He constructed the first successful model of Io's neutral clouds and studied their response to and the resulting mass loading of Jupiter's magnetosphere. This led to his serving as an interdisciplinary scientist with the Galileo mission.

Recently, Smyth had extended his research to the denser parts of the atmosphere and pioneered the consistent physical description of atmospheres through all degrees of collisionality. He was equally comfortable developing theory and analyzing observations. His meticulous penetrating research and persistent search for underlying truth, honesty, and integrity will be deeply missed.

Lynn Margulis, 1938–2011

Lynn Margulis passed away on November 22, 2011, at her home, in Amherst, Massachussetts. She was 73 years old. She was born in Chicago and enrolled at the University of Chicago when she was 14. Margulis was a renowned biologist and university professor in the Department of Geosciences at the University of Massachusetts, whose faculty Margulis joined in 1988. Prior to that she taught at the University of Boston for 22 years. She is best known for her theory on the origin of eukaryotic organelles, and her contributions to the endosymbiotic theory. She is also associated with the Gaia hypothesis, based on an idea developed by the English environmental scientist James Lovelock. The author of *Symbiotic Planet: A New Look at Evolution*, Margulis penned hundreds of research papers and many books during her illustrious career. She taught classes in environmental evolution for nearly 40 years. Margulis, who was once married to astronomer Carl Sagan and then to chemist Thomas Margulis, was elected to the National Academy of Arts and Sciences in 1983 and received the National Medal of Science in 1999.

Charles T. Kowall, 1940–2011

Charles T. Kowal died November 28, 2011, after a long battle with cancer. He was noted for his discovery of the unusual asteroid/comet 2060 Chiron, the first of the Centaurs. He also discovered two moons of Jupiter (Leda and Themisto), as well as a number of asteroids and comets. For his discoveries, Kowal was awarded the James Craig Watson Medal from the National Academy of Sciences. Subsequently, while reading through Galileo's notebooks, he found that Galileo had seen the planet Neptune, 135 years before its official discovery. Kowal worked at the Space Telescope Science Institute in support of the Hubble Space Telescope, and later worked on the Near Earth Asteroid Rendezvous (NEAR) mission at the Johns Hopkins Applied Physics Laboratory. He retired in 2006.

Sudbury impact structure.

Eugene M. Shoemaker Impact Cratering Award

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2011 recipient of the Eugene M. Shoemaker Impact Cratering Award is Olivia Thomson of the University of Puerto Rico Mayaguez. Thomson is a member of the impact studies group at the university, and studies shocked minerals from the 1.85-Ga Sudbury impact structure in Ontario, Canada.

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

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

Meteoritical Society Awards

THE METEORITICAL SOCIETY
International Society for Meteoritics and Planetary Science

2011 Gordon A. McKay Award:

Dennis Harries of the Universität Bayreuth has won the McKay Award for 2011 for a presentation entitled "Nanocrystalline P-Bearing Pentlandite and Chromium Nitrides from CM2 Chondrites Y-791198 and Y-793321." The award comes with a prize of $1000.00 (U.S.) and a certificate. This award honors the memory of Gordon A. McKay. It was endowed in 2008 thanks to the generous donations of the McKay family and many society members. The award is given each year to the student who gives the best oral presentation at the annual meeting of the society. The recipient must be a full-time student, a member of the society, and must not have previously won the McKay Award.

2012 Service Award:

The 2012 Service Award will be given to Ursula Marvin of the Harvard-Smithsonian Center for Astrophysics for documenting the history of the Meteoritical Society and the personal histories of some of the most influential people in meteoritics and planetary science. The Service Award of the Meteoritical Society honors members who have advanced the goals of the Society to promote research and education in meteoritics and planetary science in ways other than by conducting scientific research. Marvin was the society's president in 1975–1976 and celebrated her 90th birthday on August 20.

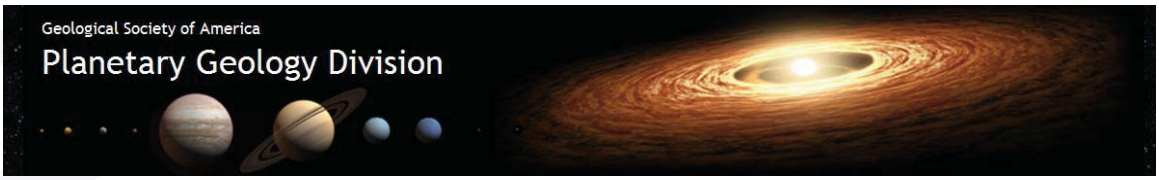
2012 Leonard Medal:

Don Burnett, Professor of Nuclear Geochemistry, Emeritus, at the California Institute of Technology, has been selected to receive the 2012 Leonard Medal, which "honors outstanding contributions to the science of meteoritics and closely allied fields." Established in 1962 to honor the society's first president, Frederick C. Leonard, the medal will be presented at the next society meeting, to be held August 12–17, 2012, in Queensland, Australia. Burnett — whose research interests include

nucleosynthesis, the abundance of elements, and the chemical evolution of the solar system, as well as meteorite and lunar sample analyses and laboratory synthesis experiments — is the principal investigator for NASA's Genesis mission, which returned samples of the solar wind to Earth in 2004. He came to Caltech as a research fellow in physics in 1963, the same year he received his Ph.D. from the University of California, Berkeley.

Other Meteoritical Society Award winners include Jan Smith, 2012 Barringer Award, and Fréderic Moynier, 2012 Nier Prize.

Planetary Geology Division of the Geological Society of America



2011 G. K. Gilbert Award:

Steven W. Squyres has been selected as the 2011 receipient of the G. K. Gilbert Award. The G. K. Gilbert Award is presented annually by the Planetary Geology Division of the Geological Society of America for outstanding contributions to the solution of fundamental problems in planetary geology in the broadest sense, which includes geochemistry, mineralogy, petrology, geophysics, geologic mapping, and remote sensing. Such contributions may consist either of a single outstanding publication or a series of publications that have had great influence in the field. The award is named for the pioneering geologist G. K. Gilbert.

2011 Stephen E. Dwornik Awards:

The Dwornik Award was started in 1991 with a generous endowment by Dr. Stephen E. Dwornik, who wished to encourage U.S. students to become involved with NASA and planetary science. The Award consists of a plaque and a monetary award given for the best student presentations (poster and oral) or a plaque for honorable mentions (poster and oral) at the annual Lunar and Planetary Science Conference (LPSC) hosted by the Lunar and Planetary Institute (LPI). The awards are managed and judged by the Planetary Geology Division of the Geological Society of America.

The 2011 winners are K. J. Zabrusky of the Colorado School of Mines (Best Graduate Oral Presentation), D. M. Hurwitz of Brown University (Honorable Mention, Graduate Oral Presentation), C. E. Viviano of the University of Tennessee (Best Graduate Poster Presentation), S. Christian of Bryn Mawr College (Best Undergraduate Poster Presentation), and N. Jamsja of Portland State State University (Honorable Mention, Undergraduate Poster Presentation).

2011 Pellas-Ryder Award:

The winner of the Pellas-Ryder Award for 2011 is Andrew W. Beck of the University of Tennessee. This award, which is jointly sponsored by the Meteoritical Society and the Planetary Geology Division of the Geological Society of America, is awarded to an undergraduate or graduate student who is first author of the best planetary science paper published in a peer-reviewed scientific journal during the year prior to the award.

2010 Nininger Meteorite Award Recipients

The Center for Meteorite Studies is pleased to announce that Andrew Beck, a graduate student at the University of Tennessee, received the 2010 Nininger Meteorite Award, and Eve L. Berger, a graduate student at the University of Arizona, received an Honorable Mention for the Award. Beck and Berger were selected from among seven Nininger Meteorite Award submissions received from students across the country. Each submission was reviewed by an international panel of experts from a broad array of fields in meteoritical science. The Award is supported by the Nininger Science of Meteoritics Fund, established in 1965 by Dr. H. H. Nininger and Mrs. Addie D. Nininger in order to promote interest in meteorite-related topics among young scientist. The Award recognizes outstanding student achievement in the "Science of Meteoritics" as embodied by an original research paper, published over the previous 12 months.

Beck's paper, "Diogenites as Polymict Breccias Composed of Orthopyroxenite and Harzburgite," sheds new light on the origin and evolution of diogenites, which are stony achondrite meteorites believed to come from the asteroid 4 Vesta. Through examination of major-, minor-, and trace-element compositional trends in multiple diogenite specimens, Beck isolated two previously convolved lithologies. This discovery enabled the creation of a new diogenite classification scheme, where subclasses of the diogenite group are distinguished using their mineral modes. His work further constrains igneous processes within the crust of Vesta, defines a new taxonomy for the diogenites, and provides context for data interpretation from the Dawn mission, which begann mapping Vesta in July 2011. Beck's research, published in Meteoritics and Planetary Science in May 2010, was conducted under the advisement of Dr. Hap McSween, himself a Nininger Meteorite Award recipient.

Andrew Beck

Berger's paper, "Evidence for Aqueous Activity on Comet 81P/Wild 2 from Sulfide Mineral Assemblages in Stardust Samples and CI Chondrites," reveals similarities in the mineralogies of CI chondrites, primitive carbonaceous chondrites whose bulk chemical composition closely matches that of the solar photosphere, and Comet Wild 2, which was sampled by the NASA Stardust mission. Iron sulfide mineral assemblages present in both CI chondrites and Wild 2 samples, in particular the copper-bearing iron sulfide cubanite ($CuFe_2S_3$), provide evidence of low-temperature (<~200°C) hydrothermal alteration within these objects. Berger's research was conducted under the advisement of former Nininger Meteorite Award recipients Drs. Lindsay Keller and Dante Lauretta.

Eve Berger

Tributes to Terrorism Victims are on Mars

In September 2001, Honeybee Robotics employees in lower Manhattan were building a pair of tools for grinding weathered rinds off rocks on Mars, so that scientific instruments on NASA's Mars Exploration Rovers Spirit and Opportunity could inspect the rocks' interiors. That month's attack on the twin towers of the World Trade Center, less than a mile away, shook the lives of the employees and millions of others. Work on the rock abrasion tools needed to meet a tight schedule to allow thorough testing before launch dates governed by the motions of the planets. The people building the tools could not spend much time helping at shelters or in other ways to cope with the life-changing tragedy of September 11. However, they did find a special way to pay tribute to the thousands of victims who perished in the attack.

The piece of metal with the American flag on it in this image of a NASA rover on Mars is made of aluminum recovered from the site of the World Trade Center towers in the weeks after their destruction. Credit: NASA/JPL-Caltech/Cornell University.

An aluminum cuff serving as a cable shield on each of the rock abrasion tools on Mars was made from aluminum recovered from the destroyed World Trade Center towers. The metal bears the image of an American flag and fills a renewed purpose as part of solar system exploration. Honeybee Robotics collaborated with the New York mayor's office; a metal-working shop in Round Rock, Texas; NASA's Jet Propulsion Laboratory in Pasadena, California; and the rover missions' science leader, Steve Squyres, at Cornell University, Ithaca, New York.

"It's gratifying knowing that a piece of the World Trade Center is up there on Mars. That shield on Mars, to me, contrasts the destructive nature of the attackers with the ingenuity and hopeful attitude of Americans," said Stephen Gorevan, Honeybee founder and chairman, and a member of the Mars rover science team.

On the morning of September 11, 2011, Gorevan was six blocks from the World Trade Center, riding his bicycle to work, when he heard an airliner hit the first tower. "Mostly, what comes back to me even today is the sound of the engines before the first plane struck the tower. Just before crashing into the tower, I could hear the engines being revved up as if those behind the controls wanted to ensure the maximum destruction. I stopped and stared for a few minutes and realized I felt totally helpless, and I left the scene and went to my office nearby, where my colleagues told me a second plane had struck. We watched the rest of the sad events of that day from the roof of our facility."

At Honeybee's building on Elizabeth Street, as in the rest of the area, normal activities were put on hold for days, and the smell from the collapse of the towers persisted for weeks. Steve Kondos, who was at the time a JPL engineer working closely with the Honeybee team, came up with the suggestion for including something on the rovers as an interplanetary memorial. JPL was building the rovers and managing the project. To carry out the idea, an early hurdle was acquiring an appropriate piece of material from the World Trade Center site. Through Gorevan's contacts, a parcel was delivered to Honeybee Robotics from the mayor's office on December 1, 2001, with a twisted plate of aluminum inside and a note: "Here is debris from Tower 1 and Tower 2."

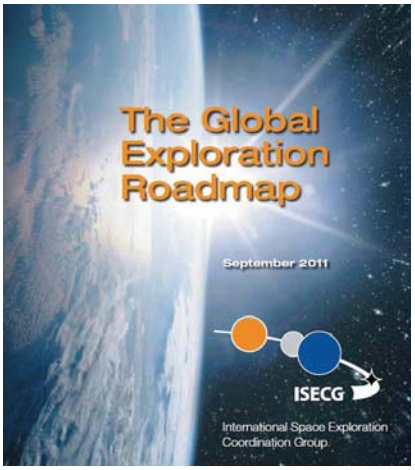
Tom Myrick, an engineer at Honeybee, saw the possibility of machining the aluminum into the cable shields for the rock abrasion tools. He hand-delivered the material to the machine shop in Texas that was working on other components of the tools. When the shields were back in New York, he affixed an image of the American flag on each.

The Mars Exploration Rover Spirit was launched from Cape Canaveral Air Force Station, Florida, on June 10, 2003. Opportunity's launch followed on July 7. Both rovers landed the following January and completed their three-month prime missions in April 2004. Nobody on the rover team or at Honeybee spoke publicly about the source of the aluminum on the cable shields until later that year.

"It was meant to be a quiet tribute," Gorevan told a New York Times reporter writing a November 2004 story about Manhattan's participation in the rover missions. "Enough time has passed. We want the families to know."

Since landing on the Red Planet, both rovers have made important discoveries about wet environments on ancient Mars that may have been favorable for supporting microbial life. Spirit ended communications in March 2010. Opportunity is still active, and researchers plan to use its rock abrasion tool on selected targets around a large crater that the rover reached in August.

One day, both rovers will be silent. In the cold, dry environments where they have worked on Mars, the onboard memorials to victims of the September 11 attack could remain in good condition for millions of years.



NASA Posts Global Exploration Roadmap

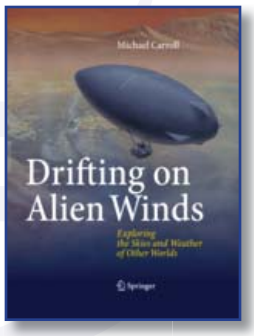
NASA is releasing the initial version of a Global Exploration Roadmap (GER) developed by the International Space Exploration Coordination Group. This roadmap is the culmination of work by 12 space agencies, including NASA, during the past year to advance coordinated space exploration. The GER begins with the International Space Station and expands human presence throughout the solar system, leading ultimately to crewed missions to explore the surface of Mars.

The roadmap identifies two potential pathways: "Asteroid Next" and "Moon Next." Each pathway represents a mission scenario that covers a 25-year period with a logical sequence of robotic and human missions. Both pathways were deemed practical approaches to address common high-level exploration goals developed by the participating agencies, recognizing that individual preferences among them may vary. To view the document, visit *www.nasa.gov/exploration/about/isecg/*.

BOOKS

Drifting on Alien Winds: Exploring the Skies and Weather of Other Worlds.

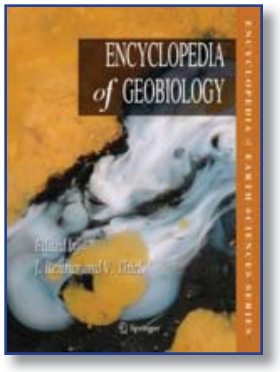
By Michael Carroll. Springer, 2011. 211 pp., Hardcover, $39.95. *www.springer.com*



Richly illustrated, including original artwork by the author, *Drifting on Alien Winds* explores the bizarre weather of alien worlds, from the blistering hurricane-force winds of Venus to the gentle methane rain showers of Saturn's giant moon Titan. Blinding bolts of lightning sizzle through Jupiter's skies, ammonia blizzards swirl through saturnian clouds, and Earth-sized cyclones pinwheel across Uranus and Neptune. Late-breaking scientific discoveries from spacecraft, observatories, and laboratories reveal the mysteries of weather across the solar system. Our knowledge of weather on other worlds has not come easily. This book introduces the inventors, engineers, and scientists who struggled to launch the first probes that would help us to understand the atmospheres of other worlds. The untold stories of early engineering feats and failures, from small Soviet Venus balloons to advanced studies of blimps and airplanes for Mars and Titan, are showcased here, along with what we have learned and are still trying to learn about alien skies.

Encyclopedia of Geobiology.

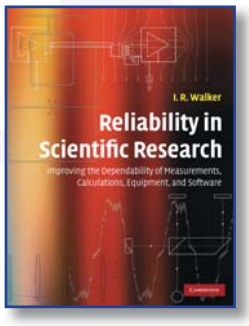
Edited by Joachim Reitner and Volker Theil. Springer, 2011. 482 pp., Hardcover, $549.00. *www.springer.com*



The interplay between geology and biology has shaped the Earth from the early Precambrian, four billion years ago. Moving beyond the borders of the classical core disciplines, geobiology strives to identify cause-and-effect chains and synergisms between the geo- and biospheres that have been driving the evolution of life in modern and ancient environments. Combining modern methods, geobiological information can be extracted not only from visible remains of organisms, but also from organic molecules, rock fabrics, minerals, isotopes, and other tracers. Exploring these processes and their signatures also creates enormous applied potentials with respect to issues of environment protection, public health, energy, and resource management. The *Encyclopedia of Geobiology* is designed as a key reference for students, researchers, teachers, and the informed public to provide basic but comprehensible knowledge on this rapidly expanding discipline at the interface between modern geo- and biosciences.

Reliability in Scientific Research: Improving the Dependability of Measurements, Calculations, Equipment, and Software.

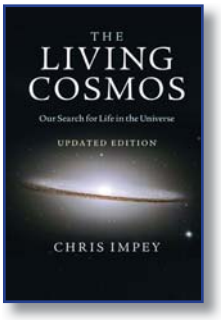
By I. R. Walker. Cambridge University Press, 2011. 610 pp., Hardcover, $79.00. *www.cambridge.org*



Covering many techniques widely used in research, this book will help researchers in the physical sciences and engineering solve troublesome — and potentially very time consuming — problems in their work. The book deals with technical difficulties that often arise unexpectedly during the use of various common experimental methods, as well as with human error. It provides preventive measures and solutions for such problems, thereby saving valuable time for researchers. Some of the topics covered are sudden leaks in vacuum systems, electromagnetic interference in electronic instruments, vibrations in sensitive equipment, and bugs in computer software. The book also discusses mistakes in mathematical calculations, and pitfalls in designing and carrying out experiments. Each chapter contains a summary of its key points, to give a quick overview of important potential problems and their solutions in a given area.

The Living Cosmos: Our Search for Life in the Universe.

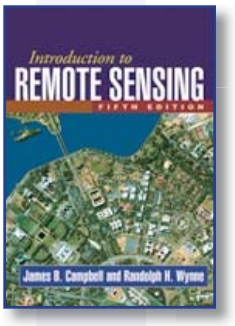
By Chris Impey. Cambridge University Press, 2011, 412 pp., Paperback, $24.99.
www.cambridge.org



Considering the development of life on Earth, the existence of life in extreme environments, and the potential for life elsewhere in the universe, this book gives a fascinating insight into our place in the universe. Impey leads the reader through the history, from the Copernican revolution to the emergence of the field of astrobiology — the study of life in the cosmos. He examines how life on Earth began, exploring its incredible variety and the extreme environments in which it can survive. Finally, Impey turns his attention to our solar system and the planets beyond, discussing whether there may be life elsewhere in the universe. Written in non-technical language, this book is ideal for anyone wanting to know more about astrobiology and how it is changing our views of life and the universe.

Introduction to Remote Sensing, Fifth Edition.

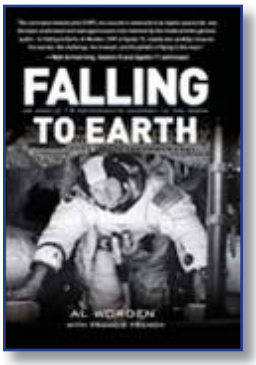
By James B. Campbell and Randolph H. Wynne. Guilford Press, 2011. 667 pp., Hardcover, $95.00. *www.guilford.com*



A leading text for undergraduate- and graduate-level courses, this book introduces widely used forms of remote sensing imagery and their applications in plant sciences, hydrology, Earth sciences, and land use analysis. The text provides comprehensive coverage of principal topics and serves as a framework for organizing the vast amount of remote sensing information available on the web. Featuring case studies and review questions, the book's 21 chapters are carefully designed as independent units that instructors can select from as needed for their courses. New to this edition is coverage of significant technological and methodological advances; a chapter on aerial photography that emphasizes digital rather than analog systems; updated discussions of accuracy assessment, multitemporal change detection, and digital preprocessing; and links to recommended online videos and tutorials.

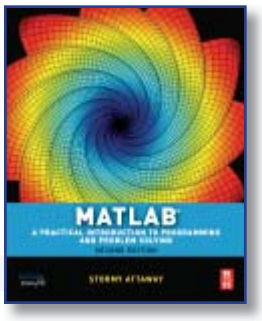
Falling to Earth: An Apollo 15 Astronaut's Journey to the Moon.

By Al Worden and Francis French. Smithsonian Books, 2011. 312 pp., Hardcover, $29.95. *www.smithsonianbooks.com*



As command module pilot for the Apollo 15 mission in 1971, Worden spent six days orbiting the Moon, including three days completely alone. During the return from the Moon to Earth he also conducted the first spacewalk in deep space, becoming the first human ever to see both the entire Earth and Moon simply by turning his head. The Apollo 15 flight capped an already-impressive career as an astronaut, including working on the pioneering Apollo 9 and Apollo 12 missions, as well as the perilous flight of Apollo 13. Nine months after his return from the Moon, he received a phone call telling him he was fired and ordering him out of his office by the end of the week. He refused to leave. What happened in those nine months, from being honored with parades and meetings with world leaders to being unceremoniously fired, has been a source of speculation for four decades. Worden has never before told the full story around the dramatic events that shook NASA and ended his spaceflight career. Readers will learn them here for the first time, along with the exhilarating account of what it is like to journey to the Moon and back.

MATLAB: A Practical Introduction to Programming and Problem Solving, Second Edition.
By Stormy Attaway. Butterworth-Heinemann, 2012, 544 pp., Paperback, $49.95. *www.elsevierdirect.com*



Assuming no knowledge of programming, this book presents both programming concepts and MATLAB's built-in functions, providing a perfect platform for exploiting its extensive capabilities for tackling engineering problems. The book starts with programming concepts such as variables, assignments, input/output, and selection statements, moves onto loops, and then solves problems using both the "programming concept" and the "power of MATLAB" side by side. In-depth coverage is given to input/output, a topic that is fundamental to many engineering applications. New to this edition are more engineering applications to help the reader learn MATLAB in the context of solving technical problems, new and revised end-of-chapter problems, stronger coverage of loops and vectorizing in a new chapter, and updates to reflect current features and functions of the current release of MATLAB.

ONLINE POSTERS

Space Shuttle Tribute Posters.
From NASA, downloadable free of charge.

NASA has issued a collection of tribute posters to the space shuttle fleet that celebrates the contributions to human space flight of Columbia, Challenger, Discovery, Atlantis, and Endeavour. Large versions of these posters now hang in Firing Room 4 of the Launch Control Center at NASA's Kennedy Space Center in Florida. These posters are available online to download free of charge and print.

www.nasa.gov/mission_pages/shuttle/flyout/multimedia/gallery/tribute_columbia.html

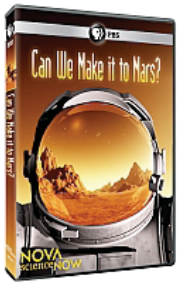
www.nasa.gov/mission_pages/shuttle/flyout/multimedia/gallery/tribute_challenger.html

www.nasa.gov/mission_pages/shuttle/flyout/multimedia/gallery/tribute_discovery.html

www.nasa.gov/mission_pages/shuttle/flyout/multimedia/gallery/tribute_atlantis.html

www.nasa.gov/mission_pages/shuttle/flyout/multimedia/gallery/tribute_endeavour.html

DVD



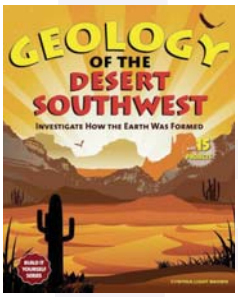
Can We Make It to Mars?
Produced by PBS, 2011, $24.99. *www.shoppbs.org*

This NOVA scienceNOW program poses the question: Can we make it to Mars? In five episodes that examine this question from different angles, host Neil deGrasse Tyson guides viewers as he explores dramatic discoveries and the frontiers of research that connect each central, provocative mystery. Program episodes include Space Dangers, Next-Generation Space Suits, Space Food, Plasma Rockets, and a profile of Vandi Verma, a member of the team that drives the Mars rovers. This one-hour DVD features descriptive video for the visually impaired.

FOR KIDS!!!

Geology of the Desert Southwest: Investigate How the Earth was Formed with 15 Projects.

By Cynthia Light Brown. Nomad Press, 2011. 128 pp., Hardcover, $21.95. *nomadpress.net*



This book helps kids learn how geology and physical geography are intertwined as they explore the unique setting of the Desert Southwest. California, Arizona, New Mexico, Nevada, Utah, Oklahoma, and Texas form this dry, often hot, region of the United States known for its saguaro cactus and the spectacular Grand Canyon. Beginning with the underlying forces of plate tectonics, young readers discover landforms such as mountains, plateaus, and canyons, then examine climate, river systems, and ecosystems. Kids will learn how mountains affect climate, and about the powerful erosive forces that produce canyons. They can explore these ideas further with hands-on experiments such as making their own swamp cooler or mimicking nature's process of evaporation by purifying water. Other titles in this Build It Yourself series include *Geology of the Pacific Northwest* and *Geology of the Great Plains and Mountain West.* For ages 9–12.

Handshake in Space: The Apollo-Soyuz Test Project.

By Sheri Tan. Soundprints, 2011. 32 pp., Hardcover. $16.95. *www.soundprints.com*

At the National Air and Space Museum in Washington, DC, Lucy and Kevin visit the U.S. and Soviet Apollo-Soyuz mission exhibit. With the help of their imaginations, they become Soviet cosmonaut Alexi A. Leonov and American astronaut Thomas Strafford, blasting off to their historic 1975 rendezvous in space. This book includes historical background notes and a glossary of key terms. For grades 2–5.

Earth, Mars & Moon to Scale Marble Collection.

Available from Shasta Visions. Three marbles with pouch and stainless steel stands, $19.50. *www.shastavisions.com*

This collection of marbles includes one 1.4-inch recycled glass natural Earth, one 1-inch Mars, and one 0.5-inch Moon. This is the perfect gift to inspire play, perspective, and peace. The geographically accurate Earth, Mars, and Moon are made in the U.S., and every set comes with an educational insert with fun facts and cosmic games to play. For ages 4 and up.

Viewmaster Space Set.

Available from 3Dstereo. Three 3-reel sets and 3-D postcard, $23.95.
www.3Dstereo.com

This collection contains three 3-reel sets — America in Space: Mercury & Gemini, Apollo Moon Landing, and Conquering Space — plus a 3-D spacewalk lenticular postcard. There are nine reels in all with a total of 63 images in 3-D, all about space exploration. Reels must be viewed with Viewmaster viewer, sold separately. For ages 3 and up.

Calendar 2011–2012

December

5–9 **AGU Fall Meeting,** San Francisco, California. *http://www.agu.org/meetings/*

5–9 **The First Kepler Science Conference,** Moffett Field, California. *http://kepler.nasa.gov/Science/keplerconference/*

11–20 **Sao Paulo Advanced School of Astrobiology,** Sao Paulo, Brazil. *http://www.astro.iag.usp.br/~spasa2011*

January

4–7 **National Radio Science Meeting,** Boulder, Colorado. *http://www.nrsmboulder.org/*

7–8 **EXOPAG 5,** Austin, Texas. *http://exep.jpl.nasa.gov/exopag/exopag5/*

8–12 **219th AAS Meeting,** Austin, Texas. *http://aas.org/meetings/aas219*

8–13 **Origin of Life,** Galveston, Texas. *http://www.grc.org/programs.aspx?year=2012&program=originlife*

17–18 **NASA Small Bodies Assessment Group Meeting #6,** Washington, DC. *http://www.lpi.usra.edu/sbag/*

23–27 **Planets Around Stellar Remnants,** Arecibo, Puerto Rico. *http://www.mpia-hd.mpg.de/PLANETS2012/index.html*

25–26 **Exploring the Planetary Science Achievable from a Balloon-Based Observatory,** Cleveland, Ohio. *http://spaceflightsystems.grc.nasa.gov/SSPO/SP/Balloon_Platform/*

31 **Exoplanet Characterization Observatory (EChO) Workshop,** Florence, Italy. *http://internal.echo-spacemission.com/index.php?option=com_content&view=article&id=89&Itemid=104*

February

1–3 **Workshop on the Early Solar System Bombardment II,** Houston, Texas. *http://www.lpi.usra.edu/meetings/bombardment2012/*

6–7 **Scientific Preparations for Lunar Exploration,** Noordwijk, The Netherlands. *http://www.congrex.nl/lunarexplorationws/*

13–15 **Conference on Life Detection in Extraterrestrial Samples,** San Diego, California. *http://www.lpi.usra.edu/meetings/lifedetection2012/*

13–15 **Science with a Wide-Field Infrared Telescope in Space,** Pasadena, California. *http://www.ipac.caltech.edu/wfir2012/*

15–17 **16th International Conference on Gravitational Microlensing,** Pasadena, California. *http://www.ipac.caltech.edu/wfir2012/*

27–28 **NASA Mars Exploration Program Analysis Group (MEPAG) Meeting #25,** Washington, DC. *http://mepag.jpl.nasa.gov/*

27–29 **Next-Gen Suborbital Researcher Conference,** Palo Alto, California. *http://nsrc.swri.org/*

27–29 **Legacy of AKARI: A Panoramic View of the Dusty Universe,** Jeju, Korea. *http://uju.snu.ac.kr/AKARI-2/*

March

3–10 **2012 IEEE Aerospace Conference,** Big Sky, Montana. *http://www.aeroconf.org*

5–8 **Observing Planetary Systems II,** Santiago, Chile. *http://www.sc.eso.org/~cdumas/OPSII.html*

9 **High Contrast Imaging and Spectroscopy,** Santiago, Chile. *http://www.sc.eso.org/~jgirard/hconis*

12–16 **STFC Graduate Course: Exoplanets and Their Host Stars,** Oxford, United Kingdom. *http://www.physics.ox.ac.uk/EAHS12/home.html*

15–17 **Second International Lunar Superconductor Applications Workshop,** Houston, Texas. *http://lsa2012.com*

19–23 **43rd Lunar and Planetary Science Conference (LPSC 2012),** The Woodlands, Texas. *http://www.lpi.usra.edu/meetings/lpsc2012/*

20–23 **From Atoms to Pebbles: Herschel's View of Star and Planet Formation**, Grenoble, France. *http://www.herschel2012.com/information/*

21–23 **NETS 2012: Nuclear and Emerging Technologies for Space,** The Woodlands, Texas. *http://anstd.ans.org/NETS2012/NETS2012Home.html*

April

3–5 **Titan Through Time II Workshop,** Greenbelt, Maryland. *http://www.astro.umd.edu/~nixon/ttt-2012.html*

15–18 **Earth and Space Conference 2012: Engineering for Extreme Environments,** Pasadena, California. *http://content.asce.org/conferences/earthspace2012/index.html*

16–20 **Astrobiology Science Conference 2012,** Atlanta, Georgia. *http://abscicon2012.arc.nasa.gov/*

22–27 **European Geosciences Union General Assembly 2012,** Vienna, Austria. *http://meetings.copernicus.org/egu2012/*

23–25 **Facets of Professional Astronomy,** Paris, France. *http://astro.u-strasbg.fr/~heck/fopa2012.htm*

23–28 **19th Young Scientists' Conference on Astronomy and Space Physics,** Kyiv, Ukraine. *http://ysc.kiev.ua*

May

6–10 **43rd Annual Meeting of the American Astronomical Society Division on Dynamical Astronomy,** Mount Hood, Oregon. *http://dda.harvard.edu/*

15–17 **Mars Recent Climate Change Workshop,** Moffett Field, California. *http://spacescience.arc.nasa.gov/mars-climate-workshop-2011/*

16–20 **Asteroids, Comets, Meteors (ACM) 2012,** Niigata, Japan. *http://chiron.mtk.nao.ac.jp/ACM2012/*

21–25 **Third Conference on Early Mars: Geologic, Hydrologic, and Climatic Evolution and the Implications for Life,** Lake Tahoe, Nevada. *http://www.lpi.usra.edu/meetings/earlymars2012/*

22–24 **IAF/AIAA Global Space Exploration Conference,** Washington, DC. *http://www.glex2012.org/index.html*

June

12–15 **Third International Planetary Dunes Workshop,** Flagstaff, Arizona. *http://www.lpi.usra.edu/meetings/dunes2012/*

16–17 **9th International Planetary Probe Short Course (IPPW-9),** Toulouse, France. *http://www.planetaryprobe.eu/*

18–22 **International Planetary Probe Workshop IPPW-9,** Toulouse, France. *http://www.planetaryprobe.eu*

24–29 **Cool Stars 17,** Barcelona, Spain. *http://www.coolstars17.net/welcome.html*

25–28 **Conference on Comparative Climatology of Terrestrial Planets,** Boulder, Colorado. *http://www.lpi.usra.edu/meetings/climatology2012/*

July

1–6 **SPIE Astronomical and Instrumentation,** Amsterdam, The Netherlands. *http://spie.org/x13662.xml*

2–15 **Nordic-NASA Summer School "Water, Ice and the Origin of Life in the Universe,"** Reykjavik, Iceland. *http://www.nordicastrobiology.net/Iceland2012/*

10–12 **NASA Small Bodies Assessment Group Meeting #7,** Pasadena, California. *http://www.lpi.usra.edu/sbag/*

14–22 **39th COSPAR Scientific Assembly,** Mysore, India. *http://www.cospar-assembly.org/*

23–27 **2012 Sagan Summer Workshop: Working with Exoplanet Light Curves,** Pasadena, California. *http://nexsci.caltech.edu/workshop/2012/*

August

4–8 **Communicating Science: A National Conference on Science Education and Public Outreach,** Tucson, Arizona. *http://www.astrosociety.org/events/meeting.html*

12–17 **75th Annual Meeting of the Meteoritical Society,** Cairns, Australia. *http://shrimp.anu.edu.au:16080/metsoc2012/Welcome.html*

13–17 **AOGS-AGU (WPGM) Joint Assembly,** Sentosa Island, Singapore. *http://www.asiaoceania.org/aogs2012/public.asp?page=home.htm*

20–31 **IAU XXVIII General Assembly,** Beijing, China. *http://www.astronomy2012.org*

27–31 **Instabilities and Structures in Proto-Planetary Disks,** Marseille, France. *http://wiki.oamp.fr/ispp/IsppWorkShop*

27–31 **Formation, Detection, and Characterization of Extrasolar Habitable Planets,** Geijing, China. *http://www.iau.org/science/meetings/future/symposia/1030/*

September

10–12 **The Mantle of Mars: Insights from Theory, Geophysics, High-Pressure Studies, and Meteorites,** Houston, Texas. *http://www.lpi.usra.edu/meetings/marsmantle2012/*

10–12 **1970–2010: The Golden Age of Solar System Exploration,** Rome, Italy. *http://goldenage2012.ifac.cnr.it/index.php/goldenage2012/goldenage2012*

19–21 **Third Planetary Crater Consortium Meeting,** Flagstaff, Arizona. *http://www.PlanetaryCraterConsortium.nau.edu*