LRO

Lunar Reconnaissance Orbiter: NASA's Next Step Back to the Moon

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Lunar Reconnaissance Orbiter: NASA's Next Step Back to the Moon

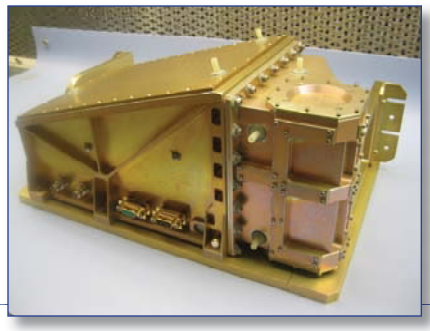
Artist's rendition of the LRO spacecraft in orbit around the Moon. Credit: NASA

On June 18, 2009, NASA took its next step back to the Moon by launching the Lunar Reconnaissance Orbiter (LRO) and its companion mission, the Lunar Crater Observation and Sensing Satellite (LCROSS). For its primary mission, LRO will orbit above the Moon at about 31 miles (50 kilometers) for one year. The spacecraft's instruments will help scientists compile high-resolution, three-dimensional maps of the lunar surface and will also survey it at many spectral wavelengths. The satellite will explore the Moon's deepest craters, examining permanently sunlit and shadowed regions, and provide understanding of the effects of lunar radiation on humans. LRO will return more data about the Moon than any previous mission.

Space seems exotic, forbidding, and remote, but imagine trying to survive winter without a heated shelter or warm clothing. Our ancestors developed these technologies because they needed room to grow; without them, we would still be confined to areas along the equator, but with them, we could live anywhere in the world. With the right technology, space is just another place for people to live.

NASA's return to the Moon led by LRO will develop technologies to open this unlimited frontier. As our closest celestial neighbor, the Moon is the natural place to test new exploration technology needed to survive in the infinite frontier of space, because the Moon presents the same challenges we will encounter throughout the universe: harmful radiation, electrified dust, and extreme temperatures. LRO will gather crucial data on the lunar environment that will help astronauts prepare for long-duration lunar expeditions.

Radiation —



The primary goal of CRaTER is to characterize the global lunar radiation environment and its biological impacts. This objective is critical if we are to implement a sustained, safe, and affordable human and robotic program to search for evidence of life, understand the history of the solar system, and prepare for future human exploration, a vision established by the President's Space Exploration Policy Directive. Credit: NASA.

Astronauts in Earth orbit are somewhat protected from space radiation by Earth's magnetic field, which acts like a shield by deflecting many cosmic rays — the high-speed electrically charged particles that are the most hazardous type of space radiation. However, the orbits of the Moon and other bodies such as asteroids are far beyond the strong and protective part of Earth's magnetic field.

Powerful magnetic storms on the Sun can blast charged particles — electrons and atomic nuclei — into space at near the speed of light. Magnetic storms that produce solar cosmic rays include solar flares, explosions in the Sun's atmosphere that can deliver the energy of a billion one-megaton nuclear bombs, or coronal mass ejections, billion-ton eruptions of electrically conducting gas moving at millions of miles per hour. Exploding stars and high-speed jets near black holes can also generate these cosmic rays.

Both types of cosmic rays present serious health hazards to unprotected astronauts. These particles act like microscopic bullets, crashing into cells and disrupting crucial molecules there, including DNA — the instructions that produce molecules essential for life and choreograph their intricate "dance" that makes life possible. Low doses over time can increase the risk of cancer by mutating DNA. High doses in short periods, like that experienced during a solar storm, can cause acute radiation sickness, leading to organ failure or even death.

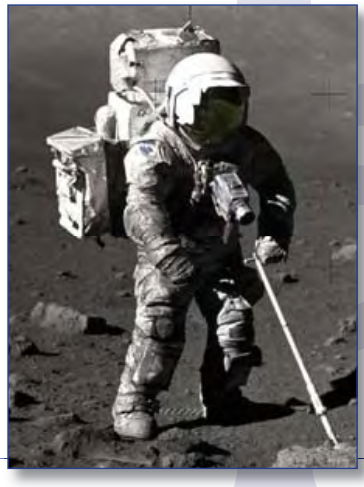
Astronauts beyond Earth orbit will need spacecraft and shelters that shield them from space radiation. The first step in designing proper radiation shields is to measure the space radiation environment. LRO has

an instrument to do this called the Cosmic Ray Telescope for the Effects of Radiation (CRaTER). This instrument will characterize the lunar radiation environment, allowing scientists to determine potential biological impacts.

"CRaTER will quantify radiation risks to astronauts from cosmic rays, a missing measurement needed to reduce risks to explorers not only at the Moon, but also throughout the local cosmos when humanity eventually ventures beyond our nearest neighbor," said Professor Harlan Spence, Principal Investigator for CRaTER at Boston University. CRaTER will also test models of radiation effects and shielding, and measure radiation absorption by human tissue-like plastic, aiding in the development of protective technologies to help keep crews safe.

Electrified Dust —

Lunar dust frequently irked the Apollo astronauts: "I think one of the most aggravating, restricting facets of lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and its restrictive, friction-like action to everything it gets on," said Apollo 17 Commander Eugene A. Cernan during the Apollo 17 technical crew debriefing.



Geologist Astronaut Harrison Schmitt, Apollo 17 lunar module pilot, uses an adjustable sampling scoop to retrieve lunar samples during the second extravehicular activity (EVA-2), at Station 5 at the Taurus-Littrow landing site. The cohesive nature of the lunar soil is born out by the "dirty" appearance of Schmitt's spacesuit. Credit: NASA.

"For instance, the simple large-tolerance mechanical devices on the Rover began to show the effect of dust as the EVAs [Extravehicular Activities or moonwalks] went on. By the middle or the end of the third EVA, simple things like bag locks and the lock which held the pallet on the Rover began not only to malfunction but to not function at all. They effectively froze. We tried to dust them and bang the dust off and clean them, and there was just no way. The effect of dust on mirrors, cameras, and checklists is phenomenal. You have to live with it but you're continually fighting the dust problem both outside and inside the spacecraft. Once you get inside the spacecraft, as much as you dust yourself, you start taking off the suits and you have dust on your hands and your face and you're walking in it. You can be as careful in cleaning up as you want to, but it just sort of inhabits every nook and cranny in the spacecraft and every pore in your skin . . . I didn't feel any aerosol dust problem at all until after rendezvous and docking when I took off my helmet in zero-g and we had the lunar module cabin fan running the whole time. I did all the transfer with my helmet and gloves off, and I'm sorry I did because the dust really began to bother me. It bothered my eyes, it bothered my throat, and I was tasting it and eating it."

Lunar dust was so annoying to the Apollo astronauts because it is both sticky and abrasive. It is likely that much of the dust is clingy for the same reason clothes tend to stick together after they come out of the dryer — it gets electrically charged. The surface of the Moon on its dayside is electrically charged by solar ultraviolet light and X-rays, and by the highly variable plasma (a gas of electrically charged particles) environment that surrounds it.

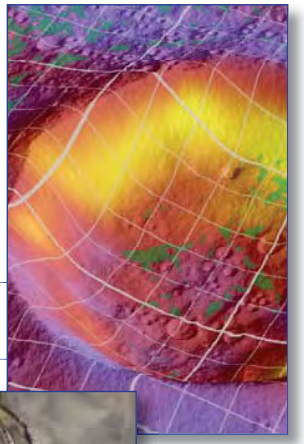
Lunar dust is abrasive because it is formed by countless impacts from microscopic meteorites. These impacts made much of the dust jagged, like shards of glass. Since the Moon's atmosphere is far too thin to blow it around and grind it smooth like wind does to sand on Earth, the dust stays sharp. Additionally, the barbed shape of the dust lets it hook into things and stick even without an electric charge.

The Apollo lunar surface missions lasted just a few days, so the dust was more of a nuisance, but it could become hazardous during the long-duration missions being planned. If tracked inside spacecraft, astronauts could inhale the dust shards. Over long periods, this might lead to lung diseases like those caused by asbestos or coal dust. The fragments could also disrupt sensitive equipment by clogging seals or grinding against moving parts.

LRO data will be used to build computer models of areas on the Moon where the electric charging and dust problems might be severe. LRO's Lunar Orbiter Laser Altimeter instrument will reveal the contours of the lunar landscape, while the Lunar Reconnaissance Orbiter Camera (LROC) will show where shadows fall as the Moon orbits Earth. The models will be enhanced by adding data from other missions, like NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE), planned for launch in 2011.

Extreme Temperatures —

The complete lunar day-night cycle is about a month long. The Apollo astronauts landed during the morning when temperatures were moderate. However, at "noon" during the two-week day, temperatures near the equator reach around 225°F (107°C), and plunge to approximately –240°F (–151°C) near the end of the two-week night. Since objects expand when heated and contract when cooled, this extreme temperature range will put stress on structures and equipment in a lunar outpost.



Artist's rendition of LRO's temperature map of a crater. Credit: NASA.

The same bitter cold resides at the bottom of permanently-shadowed polar craters. Some scientists believe there may be deposits of water ice in these craters. LCROSS is designed to impact those deposits directly and ascertain their composition. If there is enough water ice to make it practical to mine, it would save the considerable expense of hauling water up from Earth. "However, at these temperatures, ice is as hard as rock. Also, it would be a challenge to operate equipment in these frigid temperatures," said Dr. Paul Lowman of NASA Goddard, a lunar geologist.

The Diviner Lunar Radiometer Experiment was built and developed by the University of California, Los Angeles, and the Jet Propulsion Laboratory. Diviner will measure surface and subsurface temperatures from orbit. It will identify cold traps and potential ice deposits as well as rough terrain and other landing hazards. Credit: NASA/Debbie McCallum.

LROC will combine the images it takes over a year in orbit to make a movie that reveals areas getting the most sunlight, including any mountains at the polar regions that are in eternal sunshine, called permanently illuminated regions. These areas would be good places for a solar power station. The movie will also reveal the areas that are never exposed to sunlight, called permanently shadowed regions. Another instrument on LRO, named Diviner, will use infrared light emitted from the lunar surface to measure its temperature, creating a temperature map. Mission planners can then use these maps to get an idea of the temperatures expected at different locations and times.

There will always be surprises in exploration, but data from LRO, together with global mapping data from lunar orbiters launched by Europe, Japan, China, and India (see LPIB isues #101, 112, 116, and 117), will let us take a confident first step on our return to the Moon and the journey beyond.

Portions of this article were excerpted from "LRO to Help Astronauts Survive in Infinity" by Bill Steigerwald of NASA's Goddard Space Flight Center. To read the full article, visit www.nasa.gov/mission_pages/LRO/news/lro_environment.html.

Celebrate Apollo: NASA Commemorates the 40th Anniversary

NASA is planning a number of activities and events as America nears the 40th anniversary of the first Moon landing on July 20. The events will celebrate the Apollo program, its accomplishments, and the benefits to our lives today.

"Celebrate Apollo: Exploring the Moon, Discovering Earth" is an effort to engage the public and disseminate information about NASA's historic, current, and future missions. Several items have been developed to aid the celebration, including an Apollo 40th anniversary logo, calendar of events, and website.

The site NASA developed specifically for the Apollo 40th anniversary includes the special anniversary logo, an interactive feature about "Moon Trees" grown from seeds that flew on the Apollo 14 mission, and a "First Footprints" toolkit for use throughout the anniversary, which includes downloadable videos, images, and events listings. NASA's official Apollo 40th anniversary website is located at *www.nasa.gov/apollo40th*.

NASA's Apollo missions website provides easy access to various NASA resources and multimedia about the Apollo story, the program, and the history of human spaceflight, including a gallery of images from the Apollo program. The Apollo site is online at *www.nasa.gov/apollo*.

NASA also has developed an interactive Apollo program feature. On the anniversary of each Apollo mission, NASA posts a new feature that allows users to relive each mission with video, photos, and a unique animated comic. The feature can be found at *www.nasa.gov/externalflash/apollo40*.

For more information about NASA and agency programs, visit *www.nasa.gov*.

Solicitation for Contributions

Contributions to the **Lunar and Planetary Information Bulletin** (LPIB) are solicited from the planetary community and beyond. Articles exploring issues related to planetary science and exploration are welcome. Of special interest are articles describing web-based research and educational tools, meeting highlights and summaries, and descriptions of new space missions that may be of interest to our readers. Peer-reviewed research articles, however, are not appropriate for publication in the LPIB. The LPIB is published quarterly and serves the planetary research community, science libraries, educators, students, and lay readers interested in space-science-related research. Suggested topics can be e-mailed to the editors, who will provide guidelines for formatting and content.

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The Bulletin welcomes articles dealing with issues related to lunar and planetary science and exploration. The copy deadline for the next issue is September 16, 2009. Articles or announcements should be submitted via e-mail to *lpibed@lpi.usra.edu*.

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*.

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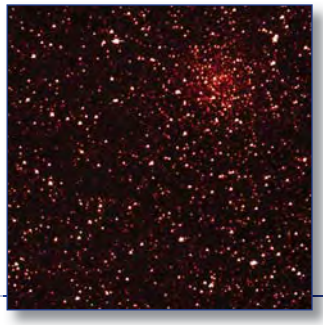
Let the Planet Hunt Begin



This image zooms into a small portion of Kepler's full field of view — an expansive, 100-square-degree patch of sky in our Milky Way galaxy. An eight-billion-year-old cluster of stars 13,000 light-years from Earth, called NGC 6791, can be seen in the image. Credit: NASA/Ames/JPL-Caltech.

NASA's Kepler spacecraft has begun its search for other Earth-like worlds. The mission, which launched from Cape Canaveral on March 6, will spend the next three-and-a-half years staring at more than 100,000 stars for telltale signs of planets. Kepler has the unique ability to find planets as small as Earth that orbit Sun-like stars at distances where temperatures are right for possible lakes and oceans.

"Now the fun begins," said William Borucki, Kepler science principal investigator at NASA's Ames Research Center. "We are all really excited to start sorting through the data and discovering the planets."

Scientists and engineers have spent the last two months checking out and calibrating the Kepler spacecraft. Data have been collected to characterize the imaging performance as well as the noise level in the measurement electronics. The scientists have constructed the list of targets for the start of the planet search, and this information has been loaded onto the spacecraft.

"If Kepler got into a staring contest, it would win," said James Fanson, Kepler project manager at NASA's Jet Propulsion Laboratory. "The spacecraft is ready to stare intently at the same stars for several years so that it can precisely measure the slightest changes in their brightness caused by planets." Kepler will hunt for planets by looking for periodic dips in the brightness of stars — events that occur when orbiting planets cross in front of their stars and partially block the light.

The mission's first finds are expected to be large, gas planets situated close to their stars. Such discoveries could be announced as early as next year. For more information about the Kepler mission, visit *www.nasa.gov/kepler* and *www.kepler.nasa.gov*.

Herschel and Planck on Way to Study Our Cosmic Roots

Artist's concept of Herschel in space. Credit: ESA.

The Herschel and Planck spacecraft successfully blasted into space on May 14 from the Guiana Space Centre in French Guiana.

The European Space Agency missions, with significant participation from NASA, hitched a ride together on an Ariane 5 rocket, but now have different journeys before them. Herschel will explore, with unprecedented clarity, the earliest stages of star and galaxy birth in the universe; it will help answer the question of how our Sun and Milky Way galaxy came to be. Planck will look back to almost the beginning of time itself, gathering new details to help explain how our universe came to be.

The spacecraft are traveling on separate trajectories to a point in the Earth-Sun system called the second Lagrangian point, four times farther away than the Moon's orbit, or an average distance of 1.5 million kilometers (930,000 miles) from Earth. They will spend the rest of their missions independently orbiting this point — located on the other side of Earth from the Sun — as they make their way around the Sun every year.

Herschel will start preparing for science operations while en route toward its operational orbit; the science mission is expected to last more than three-and-a-half years. Planck's science operations are scheduled to last a minimum of 15 months, with the possibility of an extension.

Both observatories are designed to see light our human eyes cannot. Herschel will detect light that has gone largely unexplored until now, with wavelengths in the infrared and submillimeter range. It will make the most detailed measurements yet of the cold and dark wombs where the embryos of stars and galaxies have just begun to grow.

Herschel will also be able to detect key elements and molecules involved in a star's life, tracing their evolution from atoms to potentially life-forming materials. One of these molecules is water; astronomers say Herschel will provide a greatly improved measurement of how much water there is in space.

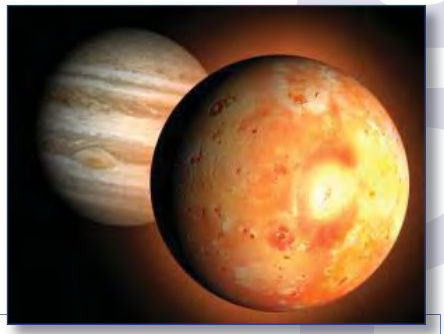
Planck will see longer-wavelength light, from the submillimeter to microwave range. It will work like the ultimate time capsule, to see light that has traveled billions of years from the newborn universe to reach us. This light, called the cosmic microwave background, contains information about the Big Bang that created space and time itself.

In order to do their jobs, the instruments on both spacecrafts will be icy cold. Liquid helium will cool the coldest of Herschel's detectors to just 0.3 K (–459°F), or 0.3° above the coldest temperature theoretically attainable in the universe. Planck's coldest detectors, which are chilled by cutting-edge coolers developed in part by JPL, will reach a frosty 0.1 K.

For more information about Herschel, visit *www.nasa.gov/herschel*, *www.herschel.caltech.edu*, or *www.esa.int/herschel*. More information about Planck is available at *www.nasa.gov/planck* and *www.esa.int/planck*.

Solar System's Most Volcanic Body May Go Dormant

The most volcanically active body in the solar system has just received a death sentence. Jupiter's moon Io, whose surface erupts with active volcanos, will one day become dormant, a new study analyzing more than 100 years of observations suggests. The results were published in a recent issue of *Nature* (vol. 459, p. 957).



Jupiter's massive size, coupled with Io's close orbital distance to the planet, expose the moon to powerful gravitational forces. These forces constantly deform the moon, generating the heat that powers its volcanism. Similar, but less powerful, "tidal" forces are thought to power geysers of water vapor erupting from Saturn's icy moon Enceladus. Credit: V. Lainey/IMCCE-Paris Observatory.

Io, which is about the size of Earth's Moon and is Jupiter's closest large satellite, is covered with lava flows and dozens of active volcanos. The heat for this activity comes from the fact that the moon travels on an elongated path around Jupiter, and therefore feels the giant planet's gravity at different strengths along its orbit. This varying pull causes its body to deform, producing bulges that move its surface up and down by an estimated 10 meters per orbit. This generates heat that powers the moon's volcanism.

But it will not always be so, according to a new study led by Valéry Lainey of the Paris Observatory in France. If Io were Jupiter's only satellite, the planet's intense gravity would eventually pull the nearby moon into a circular orbit. The reason it travels on an elliptical path instead is because of special gravitational interactions with its nearest large sister moons, Europa and Ganymede. For every orbit that Ganymede makes, Europa makes two and Io four — a type of gravitational relationship called a Laplace resonance. But Lainey and colleagues have found that the moons may, in fact, be moving out of their resonance — Europa and Ganymede are gradually drifting away from Jupiter, while Io is moving towards the planet.

The team came to these conclusions after carrying out numerical calculations of Io's orbital motion and plugging in observations of Io, Europa, and Ganymede taken between 1891 and 2007. Although different gravitational forces act on Io, with some pulling it toward Jupiter and others pushing it away, the new study suggests the inward forces win out.

Io's spin gradually increases at the expense of its orbital speed. When it is closest to Jupiter, gravity pulls on Io's nearside to make the moon spin faster. "Io loses orbital energy, its orbital period decreases, and it moves inward toward Jupiter," explains Gerald Schubert of the University of California, Los Angeles, in a commentary accompanying the study.

"Others have attempted the same calculation in the past, but with poorly constrained — and often contradictory — results, probably owing to approximations made in their orbital dynamical models," Schubert writes.

It is not clear exactly when the moons will break free from their resonance. "If this occurs on a short timescale, say [100 million] years or less, then we have been lucky to see Io in its volcanic glory, because dormancy will be the fate of Io when the resonance is broken," Schubert writes.

Soft Ground Puts Spirit in Danger Despite Gain in Daily Energy

The five wheels that still rotate on NASA's Mars Exploration Rover Spirit have been slipping severely in soft soil during recent attempts to drive, sinking the wheels about halfway into the ground. The rover team of engineers and scientists has suspended driving Spirit temporarily while studying the ground around the rover and planning simulation tests of driving options with a test rover at NASA's Jet Propulsion Laboratory.

A new image of Spirit's underbelly is helping engineers assess the rover's current state and plan her escape from soft soil. The panoramic mosaic of multiple images was taken by the microscopic imager instrument at the end of Spirit's robotic arm — the first time that imager has been used to assess the underside and wheels of the rover. The image appears blurred because the microscopic camera was designed to focus on targets just a few centimeters in front of its optics. Credit: NASA/JPL/USGS.

Both Spirit and Opportunity have operated more than five years longer than their originally planned missions of three months on Mars and have driven much farther than designed. The rover team has so far developed ways to cope with various symptoms of aging on both rovers. Spirit has been driving counterclockwise from north to south around a low plateau called "Home Plate" for two months. The rover progressed 122 meters (400 feet) on that route before reaching its current position.

The digging-in of Spirit's wheels has raised concerns that the rover's belly pan could now be low enough to contact rocks underneath the chassis, which would make getting out of the situation more difficult. The right-front wheel on Spirit stopped working three years ago. Driving with just five powered wheels while dragging or pushing an immobile wheel adds to the challenge of the situation.

Favorably, wind has recently removed some of the dust accumulated on Spirit's solar panels. This increases the rover's capability for generating electricity. "The improved power situation buys us time," Callas said. "We will use that time to plan the next steps carefully. We know that dust storms could return at any time, although the skies are currently clear."

Behavioral problems that Spirit exhibited in early April — episodes of amnesia, computer resets, and failure to wake for communications sessions — have not recurred in the past three weeks, although investigations have yet to diagnose the root causes. For more information about the Mars rovers, visit *www.nasa.gov/rovers*.

MESSENGER Spacecraft Reveals a Very Dynamic Planet Mercury

A NASA spacecraft gliding over the surface of Mercury has revealed that the planet's atmosphere, the interaction of its surrounding magnetic field with the solar wind, and its geological past display greater levels of activity than scientists first suspected. The probe also discovered a previously unknown large impact basin about 430 miles in diameter — equal to the distance between Washington and Boston.

Analyses of these new findings and more are reported in four papers published in the May 1 issue of *Science* magazine. The data come from the MErcury Surface, Space Environment, Geochemistry, and Ranging spacecraft, known as MESSENGER. On October 6, 2008, the probe flew by Mercury for the second time, capturing more than 1200 high-resolution and color images of the planet. The probe unveiled another 30% of the planet's surface that had never been seen by previous spacecraft, gathering essential data for planning the remainder of the mission.

"This second Mercury flyby provided a number of new findings," said Sean Solomon, the probe's principal investigator from the Carnegie Institution of Washington. "One of the biggest surprises was how strongly the dynamics of the planet's magnetic field-solar wind interaction changed from what we saw during the first Mercury flyby in January 2008. The discovery of a large and unusually well preserved impact basin shows concentrated volcanic and deformational activity."

The spacecraft also made the first detection of magnesium in Mercury's thin atmosphere, known as an exosphere. This observation and other data confirm that magnesium is an important constituent of Mercury's surface materials. The probe's Mercury Atmospheric and Surface Composition Spectrometer instrument detected the magnesium. Finding magnesium was not surprising to scientists, but seeing it in the amounts and distribution observed was unexpected. The instrument also measured other exospheric constituents, including calcium and sodium.

"This is an example of the kind of individual discoveries that the science team will piece together to give us a new picture of how the planet formed and evolved," said William McClintock, co-investigator and lead author of one of the four papers. McClintock, who is from the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder, suspects that additional metallic elements from the surface, including aluminum, iron, and silicon, also contribute to the exosphere.

This mosaic was assembled using Narrow Angle Camera (NAC) images acquired as the MESSENGER spacecraft approached the planet during the mission's second Mercury flyby. The Rembrandt impact basin is seen at the center of the mosaic, as night was falling across the basin's eastern edge. Credit: NASA/JHUAPL/ Arizona State University/Carnegie Institution of Washington.

The variability that the spacecraft observed in Mercury's magnetosphere, the volume of space dominated by the planet's magnetic field, so far supports the hypothesis that the great day-to-day changes in Mercury's atmosphere may be a result of changes in the shielding provided by the magnetosphere. "The spacecraft observed a radically different magnetosphere at Mercury during its second flyby compared with its earlier January 14 encounter," said James Slavin from NASA's Goddard Space Flight Center. Slavin is a mission co-investigator and lead author of one of the papers. "During the first flyby, important discoveries were made, but scientists didn't detect any dynamic features. The second flyby witnessed a totally different situation."

The spacecraft's discovery of the impact basin, called Rembrandt, is the first time scientists have seen terrain well exposed on the floor of a large impact basin on Mercury. Landforms such as those revealed on the floor of Rembrandt usually are buried completely by volcanic flows. "This basin formed about 3.9 billion years ago, near the end of the period of heavy bombardment of the inner solar system," said Thomas Watters from the Smithsonian Institution in Washington, a participating scientist and lead author of one paper. "Although ancient, the Rembrandt basin is younger than most other known impact basins on Mercury."

Half of Mercury was unknown until a little more than a year ago. Globes of the planet were blank on one side. Spacecraft images have enabled scientists to see 90% of the planet's surface at high resolution. The spacecraft's nearly global imaging coverage of the surface after the second flyby gives scientists fresh insight into how the planet's crust was formed.

"After mapping the surface, we see that approximately 40% is covered by smooth plains," said Brett Denevi of Arizona State University in Tempe, a team member and lead author of a paper. "Many of these smooth plains are interpreted to be of volcanic origin, and they are globally distributed. Much of Mercury's crust may have formed through repeated volcanic eruptions in a manner more similar to the crust of Mars than to that of the Moon."

Scientists continue to examine data from the first two flybys and are preparing to gather more information from a third flyby of the planet on September 29.

"The third Mercury flyby is our final dress rehearsal for the main performance of our mission, the insertion of the probe into orbit around Mercury in March 2011," said Solomon. "The orbital phase will be like staging two flybys per day and will provide the continuous collection of information about the planet and its environment for one year. Mercury has been coy in revealing its secrets slowly so far, but in less than two years the innermost planet will become a close friend." For more information about MESSENGER, visit *www.nasa.gov/messenger*.

NASA Releases Interactive 3-D Views of Space Station, New Mars Rover

NASA recently released an interactive, 3-D photographic collection of internal and external views of the International Space Station and a model of the next Mars rover. NASA and Microsoft's Virtual Earth team developed the online experience with hundreds of photographs and Microsoft's photo imaging technology called Photosynth. Using a click-and-drag interface, viewers can zoom in to see details of the space station's modules and solar arrays or zoom out for a more global view of the complex.

"Photosynth brings the public closer to our spaceflight equipment and hardware," said Bill Gerstenmaier, associate administrator for Space Operations at NASA Headquarters. "The space station pictures are not simulations or graphic representations but actual images taken recently by astronauts while in orbit. Although you're not flying 220 miles above the Earth at 17,500 miles an hour, it allows you to navigate and view amazing details of the real station as though you were there."

The software uses photographs from standard digital cameras to construct a 3-D view that can be navigated and explored online. "This stunning collection of photographs using Microsoft's Photosynth interactive 3-D imaging technology provides people around the world with an exciting new way to explore the space station and learn about NASA's upcoming Mars Science Laboratory mission," said Pete Worden, director of NASA's Ames Research Center. "This collaboration with Microsoft offers the public the opportunity to participate in future exploration using this innovative technology."

This is a view of a model of the Mars Science Lab in Photosynth. Credit: NASA/JPL.

The Mars rover imagery gives viewers an opportunity to preview the hardware of NASA's Mars Science Laboratory, currently being assembled for launch to the Red Planet in 2011. "We are making this enhanced viewing experience available from the Mars Science Laboratory project because we're eager for the public to share in the excitement that's building for this mission," said Fuk Li, manager of NASA's Mars Exploration Program.

NASA's Photosynth collection can be viewed at *www.nasa.gov/photosynth*. The NASA images also can be viewed on Microsoft's Virtual Earth website at *www.microsoft.com/virtualearth*.

While roaming through different components of the station, the public also can join in a scavenger hunt. NASA has a list of items that can be found in the Photosynth collection. These items include a station crew patch, a spacesuit, and a bell that is traditionally used to announce the arrival of a visiting spacecraft. Clues to help in the hunt will be posted on NASA's Facebook page and @NASA on Twitter. To access these sites, visit *www.nasa.gov/collaborate*.

NASA astronaut Sandra Magnus took the internal images of the space station during the 129 days she lived aboard the complex. She photographed the station's exterior while onboard the space shuttle Discovery, which flew her back to Earth in March. The rover images were taken of a full-scale model in a Mars-simulation testing area at JPL. Photosynth has multiple potential benefits for NASA. Engineers can use it to examine hardware, and astronauts can use it for space station familiarization training.

For more information about the space station, visit *www.nasa.gov/station*. For more information about the Mars Science Laboratory, visit *mars.jpl.nasa.gov/msl*.

NASA Team Finds Riches in Meteorite Treasure Hunt

Just before dawn on October 7, 2008, an SUV-sized asteroid entered Earth's atmosphere and exploded harmlessly over the Nubian Desert of northern Sudan. Scientists expected the asteroid, called 2008 TC3, had blown to dust in the resulting high-altitude fireball. What happened next excited the scientific community.

Muawia Shaddad of the University of Khartoum, Sudan, and NASA meteor astronomer Peter Jenniskens join students of the University of Khartoum at the location of one of the larger finds of the remnants of asteroid 2008 TC3 from the first search campaign. Credit: NASA.

Peter Jenniskens, a meteor astronomer with the SETI Institute in Mountain View, California, joined Muawia Shaddad of the University of Khartoum in Sudan to search for possible extraterrestrial remnants from the asteroid. A paper on their findings was featured in the March 26 issue of the journal *Nature*. Now, for the first time, scientists are studying recovered celestial meteorites that have a definitive link with an asteroid from space. This presents the science community an unprecedented opportunity to interpret asteroid data and learn more about the origins and differentiations between asteroids and may provide better answers about the formation of our solar system.

The asteroid was discovered by a telescope of the NASA-sponsored Catalina Sky Survey. Astronomers and scientists around the world tracked and scanned TC3 for 20 hours prior to its demise. This marked the first time a celestial object was located prior to entering Earth's atmosphere. The asteroid had a velocity of 27,700 miles per hour when it entered the atmosphere. It created a fiery

trail 51 miles long before exploding 121,000 feet from the ground. “When Dr. Shaddad and I first arrived and started interviewing eyewitnesses, things looked very bleak,” said Jenniskens. “They all described an immense explosion in the sky, but none had seen any material flying out of the fireball.”

The location and subsequent recovery was like searching for a needle in a haystack. Scientists used what they referred to as a treasure map to locate the meteorites. NASA’s Jet Propulsion Laboratory produced a chart that gave the recovery team its search grid and specific target area. “My work usually begins and ends with trajectories of objects in space,” said Steve Chesley, a scientist at NASA’s Near-Earth Object Program Office. “We had accurately predicted when and where TC3 would enter over the Sudan. Jenniskens was asking for a map of where any surviving fireball fragments could have landed. That was a first for the Near-Earth Object Program Office.”

Armed with the treasure map, Jenniskens, Shaddad, and students and staff from the University of Khartoum began their trek in the afternoon of December 6, 2008. After a three-day search, the team had scoured 18 miles along Chesley’s asteroid path and recovered 15 samples with a total mass of 1.24 pounds. Scientists observed the meteorites to be porous, rocky material, rounded like a pebble, with a broken face, and very black in color.

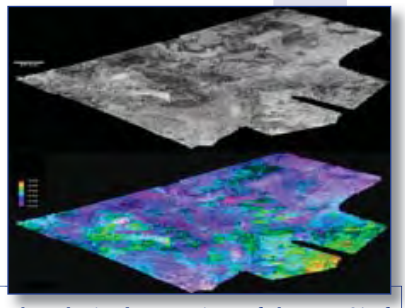
Jenniskens and the Khartoum team visited the site on two more occasions and collected 280 meteorites with a total mass of approximately 11 pounds. Samples were sent for analysis to Ames, NASA’s Johnson Space Center (JSC) in Houston, the Carnegie Institution of Washington, and Fordham University in New York.

“We certainly found a treasure,” said Michael Zolensky, a cosmic mineralogist at JSC. “We have never seen a meteorite on Earth exactly like this one because they are so fragile that they explode high in the atmosphere. The samples appear to have originated from the surface of the original asteroid, making them especially valuable to planetologists explaining the geological history of primitive bodies and planning spacecraft missions to asteroids.” By measuring how asteroid 2008TC3 reflected sunlight in space and comparing it to how the meteorites found on the ground reflected sunlight, the team concluded that the meteorites came from the surface of an F-class asteroid in our solar system’s asteroid belt. Furthermore, the team determined that the meteorite was what astronomers refer to as a polymic ureilite, in other words, a very rare and unusually fragile, dark rock.

For more information about NASA’s Near-Earth Object office, visit *neo.jpl.nasa.gov*. For more images from the 2008TC4 detection and recovery effort, visit *www.nasa.gov/topics/solarsystem/tc3*.

Cassini Provides Virtual Flyover of Saturn’s Moon Titan

“Fly me to the moon” — to Saturn’s moon Titan, that is. New Titan movies and images are providing a bird’s-eye view of the moon’s Earth-like landscapes. The new flyover maps show, for the first time, the 3-D topography and height of the 1200-meter (4000-foot) mountain tops, the north polar lake country, the vast dunes more than 100 meters (300 feet) high that crisscross the moon, and the thick flows that may have oozed from possible ice volcanos. The topographic maps were made from stereo pairs of radar images. They are available at *saturn.jpl.nasa.gov* and *www.nasa.gov/cassini*.



Cassini’s radar mapper has obtained stereo views of close to 2% of Titan’s surface over the last five years. Credit: NASA/JPL/USGS.

Cassini radar team member Randy Kirk with the Astrogeology Science Center at the U.S. Geological Survey in Flagstaff created the maps. He used some of the 20 or so areas where two or more overlapping radar measurements were obtained during 19 Titan flybys. These stereo overlaps cover close to 2% of Titan’s surface. The process of making topographic maps from them is just beginning, but the results already reveal some of the diversity of Titan’s geologic features.

High and low features are shown in unprecedented detail at about 2.4-kilometer (1.5-mile) resolution. The maps show some features that may be volcanic flows. These flows meander across a shallow basin in the mountains. One area suspected to be an ice volcano, Ganesa Macula, does not appear to be a volcanic dome. It may still have originated as a volcano, but it’s too soon to know for sure. “It could be a volcanic feature, a crater, or something else that has just been heavily eroded,” added Kirk.

The stereo coverage includes a large portion of Titan’s north polar lakes of liquid ethane and methane. Based on these topographical models, scientists are better able to determine the depth of lakes. The highest areas

surrounding the lakes are some 1200 meters (about 4000 feet) above the shoreline. By comparing terrain around Earth to the Titan lakes, scientists estimate their depth is likely about 100 meters (300 feet) or less.

More 3-D mapping of these lakes will help refine these depth estimates and determine the volume of liquid hydrocarbons that exist on Titan. This information is important because these liquids evaporate and create Titan's atmosphere. Understanding this methane cycle can provide clues to Titan's weather and climate.

Launched in 1997, Cassini completed its primary four-year mission in 2008 and is now in extended mission operations, which run through September 2010. Over the course of the mission, Cassini plans to map more than 3% of Titan's surface in 3-D. About 38% of Titan's surface has been mapped with radar so far. On March 27, Cassini completed its 52nd targeted flyby of Titan.

Spitzer Telescope Warms up to New Career

The primary mission of NASA's Spitzer Space Telescope has ended after more than five-and-a-half years of probing the cosmos with its keen infrared eye. On May 15, the telescope ran out of the liquid helium needed to chill some of its instruments to operating temperatures. The end of the coolant began a new era for Spitzer. The telescope started its "warm" mission with two channels of one instrument still working at full capacity. Some of the science explored by a warm Spitzer will be the same, and some will be entirely new.

The "Cat's Eye" nebula, or NGC 6543, is a well-studied example of a "planetary nebula." Such objects are the glowing remnants of dust and gas expelled from moderate-sized stars during their last stages of life. The Spitzer Space Telescope has studied many such planetary nebulae in infrared light, including a variety of more distant ones, which have helped scientists identify a population of carbon-bearing stars near our galaxy's center. The image is a composite of data from Spitzer's infrared array camera. Credit: NASA/JPL-Caltech.

"We like to think of Spitzer as being reborn," said Robert Wilson, Spitzer project manager at NASA's Jet Propulsion Laboratory. "Spitzer led an amazing life, performing above and beyond its call of duty. Its primary mission might be over, but it will tackle new scientific pursuits, and more breakthroughs are sure to come."

For a telescope to detect infrared light — essentially heat — from cool cosmic objects, it must have very little heat of its own. During the past five years, liquid helium has run through Spitzer's "veins," keeping its three instruments chilled to –456°F (–271°C), or less than 3° above absolute zero, the coldest temperature theoretically attainable. The cryogen was projected to last as little as two-and-a-half years, but Spitzer's efficient design and careful operations enabled it to last more than five-and-a-half years.

Spitzer's new "warm" temperature is still quite chilly at –404°F (–242°C) — much colder than a winter day in Antarctica when temperatures sometimes reach –75°F (–59°C). This temperature rise means two of Spitzer's instruments — its longer-wavelength multiband imaging photometer and its infrared spectrograph — will no longer be cold enough to detect cool objects in space. However, the telescope's two shortest-wavelength detectors in its infrared array camera will continue to function perfectly. They will still pick up the glow from a range of objects: asteroids in our solar system, dusty stars, planet-forming disks, gas-giant planets, and distant galaxies. In addition, Spitzer still will be able to see through the dust that permeates our galaxy and blocks visible-light views.

Perhaps the most revolutionary and surprising Spitzer findings involve planets around other stars, called exoplanets. Exoplanets are, in almost all cases, too close to their parent stars to be seen from our Earthly point of view. Nevertheless, planet hunters continue to uncover them by looking for changes in the parent stars. Before Spitzer, everything we knew about exoplanets came from indirect observations such as these.

In 2005, Spitzer detected the first light, or photons, from an exoplanet. In a clever technique, now referred to as the secondary-eclipse method, Spitzer was able to collect the light of a hot, gaseous exoplanet and learn about its temperature. Further detailed spectroscopic studies later revealed more about the atmospheres, or "weather," on similar planets. More recently, Spitzer witnessed changes in the weather on a wildly eccentric gas exoplanet — a storm of colossal proportions brewing up in a matter of hours before quickly settling down.

"Nobody had any idea Spitzer would be able to directly study exoplanets when we designed it," said Michael Werner, Spitzer Project Scientist at JPL. "When astronomers planned the first observations, we had no idea if they would work. To our amazement and delight, they did."

Some of Spitzer's new pursuits include refining estimates of Hubble's constant, or the rate at which our universe is stretching apart; searching for galaxies at the edge of the universe; assessing how often potentially hazardous asteroids might impact Earth by measuring the sizes of asteroids; and characterizing the atmospheres of gas-giant planets expected to be discovered soon by NASA's Kepler mission. More information about Spitzer is online at *www.nasa.gov/spitzer* and *www.spitzer.caltech.edu/spitzer*.

Spitzer Catches Star Cooking Up Comet Crystals

Scientists have long wondered how tiny silicate crystals, which need sizzling high temperatures to form, have found their way into frozen comets, born in the deep freeze of the solar system's outer edges. The crystals would have begun as noncrystallized silicate particles, part of the mix of gas and dust from which the solar system developed. A team of astronomers believes they have found a new explanation for both where and how these crystals may have been created, by using NASA's Spitzer Space Telescope to observe the growing pains of a young, Sun-like star. Their study results, which appear in the May 14 issue of *Nature*, provide new insight into the formation of planets and comets.

This image shows a young Sun-like star encircled by its planet-forming disk of gas and dust. The silicate that makes up most of the dust would have begun as noncrystallized, amorphous particles. Credit: NASA/JPL-Caltech.

The researchers found that silicate appears to have been transformed into crystalline form by an outburst from a star. They detected the infrared signature of silicate crystals on the disk of dust and gas surrounding the star EX Lupi during one of its frequent flare-ups, or outbursts, seen by Spitzer in April 2008. These crystals were not present in Spitzer's previous observations of the star's disk during one of its quiet periods.

"We believe that we have observed, for the first time, ongoing crystal formation," said one of the paper's authors, Attila Juhasz of the Max-Planck Institute for Astronomy in Heidelberg, Germany. "We think that the crystals were formed by thermal annealing of small particles on the surface layer of the star's inner disk by heat from the outburst. This is a completely new scenario about how this material could be created."

Annealing is a process in which a material is heated to a certain temperature at which some of its bonds break and then reform, changing the material's physical properties. It is one way that amorphous silicate dust can be transformed into crystalline form. Scientists previously had considered two different possible scenarios in which annealing could create the silicate crystals found in comets and young stars' disks. What Juhasz and his colleagues found at EX Lupi didn't fit either of the earlier theories. "We concluded that this is a third way in which silicate crystals may be formed with annealing, one not considered before," said the paper's lead author, Peter Abraham of the Hungarian Academy of Sciences' Konkoly Observatory in Budapest, Hungary.

EX Lupi is a young star, possibly similar to our Sun four or five billion years ago. Every few years, it experiences outbursts, or eruptions, that astronomers think are the result of the star gathering up mass that has accumulated in its surrounding disk. These flare-ups vary in intensity, with really big eruptions occurring every 50 years or so. In 2005, the silicate on the surface of the star's disk appeared to be in the form of amorphous grains of dust. In 2008, the spectrum showed the presence of crystalline silicate on top of amorphous dust. The crystals appear to be forsterite, a material often found in comets and in protoplanetary disks. The crystals also appear hot, evidence that they were created in a high-temperature process, but not by shock heating. If that were the case, they would already be cool.

"At outburst, EX Lupi became about 100 times more luminous," said Juhasz. "Crystals formed in the surface layer of the disk but just at the distance from the star where the temperature was high enough to anneal the silicate — about 1000 Kelvin [1340°F] — but still lower than 1500 Kelvin [2240°F]. Above that, the dust grains will evaporate." The radius of this crystal formation zone, the researchers note, is comparable to that of the terrestrial-planet region in the solar system.

"These observations show, for the first time, the actual production of crystalline silicates like those found in comets and meteorites in our own solar system," said Spitzer Project Scientist Michael Werner of NASA's Jet Propulsion Laboratory. "So what we see in comets today may have been produced by repeated bursts of energy when the Sun was young."

40th Lunar and Planetary Science Conference

Although it may be hard to believe, this year marked the 40th year of the annual Lunar and Planetary Science Conference. The first conference (the Apollo 1l Lunar Science Conference) was held in January 1970 in downtown Houston, and was attended by more than 500 scientists from 9 countries, including all 142 principal investigators for the Apollo 11 samples. The first abstract volume contained 141 abstracts, and the agenda for the meeting focused almost exclusively on the exciting new data being gleaned from the first samples ever returned to Earth from another body in the solar system. Coverage of this first conference was featured in a special issue of the journal *Science* (volume 167, issue 3918).

Thirty-nine years later, the conference continues to grow and expand. In 1971, the name was simply the "Lunar Science Conference," and in 1978, the name was changed to "Lunar and Planetary Science Conference (LPSC)" to reflect the ever-widening breadth of planetary science covered by the meeting. That growth is reflected in the number of attendees and published abstracts; the CD-ROM for the 40th LPSC includes 1549 abstracts, and the meeting was attended by more than 1500 participants from 24 countries. Among those in attendance at this year's LPSC were a handful of scientists who had actually attended all 40 conferences, which of course offered a unique photo opportunity!

This expansion in the size and scope of the conference has also been reflected in the venue. The first two conferences were held in downtown Houston, but in 1972, the meeting was moved to an auditorium at the NASA Johnson Space Center (JSC). Quickly outgrowing a single room, the meeting moved to the Gilruth Center, where it remained until the events of September 11, 2001, precipitated extreme security measures that required moving the meeting offsite. In truth, however, the conference had outgrown the Gilruth Center years before, and moving to the new location, South Shore Harbour Resort & Conference Center in League City, offered many advantages.

However, the lack of a true convention center in the Clear Lake area again became evident as the size of the conference continued to grow. While South Shore offered meeting rooms that could accommodate greater numbers than those available at Gilruth, they soon filled to capacity, and the attendance at many of the oral sessions was often standing room only, requiring overflow rooms and outside television monitors. The poster sessions were held at the same complex, but in a separate building that housed the gymnasium and tennis courts. Not only did access to the posters require a five- to ten-minute walk (outside, in the elements), but on the evenings of the poster sessions the facility was extremely crowded, hot, and smelled . . . well, it smelled like a gym (no surprise there!).

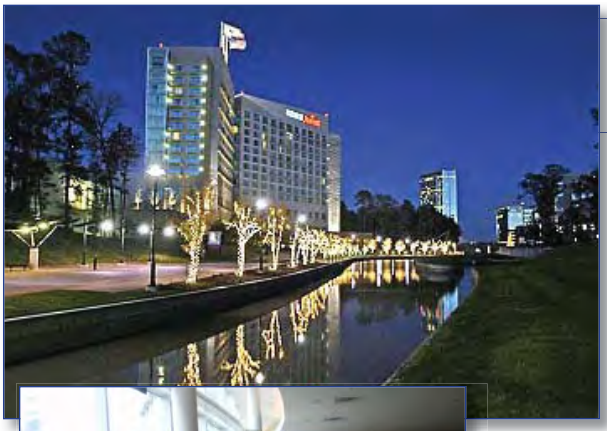
After the conclusion of the 39th LPSC in 2008, it was clear that there was no choice but to move the conference to a larger venue. For two years the conference organizers had been searching for alternative locations for the meeting, with priority given to a single meeting site during the month of March, inexpensive local hotels within a two- to three-mile radius, plenty of restaurants within walking distance, and an environment that strongly favored interaction and scientific discourse. Unfortunately, there is no single meeting venue in the Clear Lake–League City area that can accommodate a meeting as large as LPSC. Numerous venues across the country were considered, but besides the cost factor, the organizers wanted to maintain the historic connection to Houston, the home of NASA's Johnson Space Center and the Lunar and Planetary Institute.

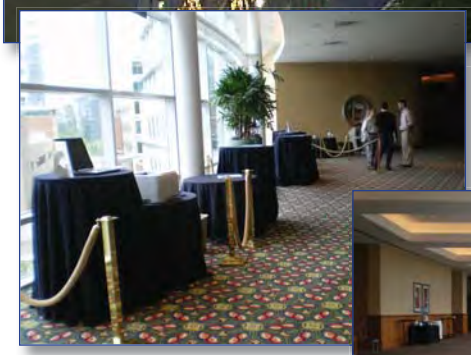
After considerable research, The Woodlands Waterway Marriott Hotel and Convention Center, located just north of the George Bush Intercontinental Airport, was selected as the new venue for the LPSC. Not only does this venue provide more than ample space for the ever-expanding conference, but multiple ballrooms, each seating more than 500, will accommodate future expansion. The Town Center Exhibit Hall provides approximately 40,000 square feet for posters and exhibits. Wide, comfortable prefunction and lobby areas and pleasant outdoor spaces provide ample room for collegial interaction.

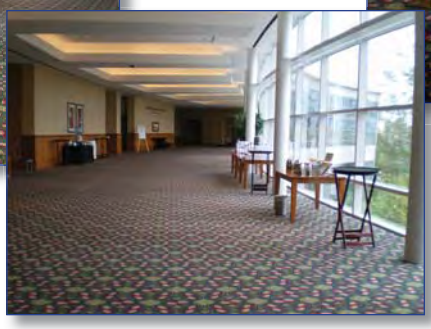
As usual, the conference provided a veritable smorgasbord of the latest research in the field of planetary science, featuring sessions covering such diverse topics as the origin and early evolution of the Moon, planetary differentiation, the structure and origin of presolar grains, chondrite parent-body processes, magmatic volatiles, the origins and relationships of interstellar matter, science instruments for the Mars Science Lander, martian volcanism, and much more. Special sessions included results from the Kaguya, Chang'e-1, and Chandrayaan-1 lunar missions; MESSENGER's global perspective on the innermost planet, Mercury; the icy satellites of Jupiter and Saturn; and the atmosphere of Venus, including discussion of Venus Express and future missions to Venus.

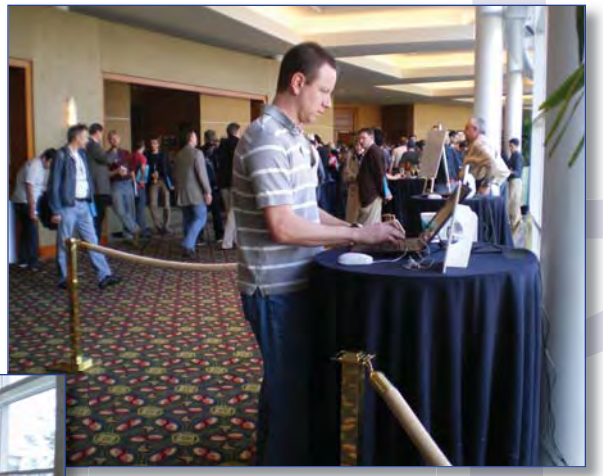
The plenary session on Monday afternoon featured the Masursky Lecture by Alan Stern, who presented the talk entitled "Planet Categorization and Planetary Science: Coming of Age in the 21st Century." Recipients of the 2008 Dwornik student awards were also recognized and honored during the plenary session, and scientists and students had an opportunity to meet and mingle during the student/scientist reception on Monday evening, which immediately followed the NASA Headquarters briefing to the community.

Plans are already underway for the 41st LPSC, which will be held at The Woodlands Waterway Marriott Hotel and Convention Center on **March 1–5, 2010**. Conference information will be posted on the meeting website at *www.lpi.usra.edu/meetings/lpsc2010*. The abstract deadline will be **December 10, 2009**, so mark your calendars now. We hope to see you there!









The Woodlands Waterway Marriott Hotel and Convention Center has a lovely natural exterior setting and spacious interior that worked well with the new self-registration systen.

Some participants have attended all 40 conferences!
From top left: Dimitri Papanastassiou, Don Burnett, Bob Clayton, Larry Nyquist, and Dominic Noto (LPSC shuttle service provider). From bottom left: Everett Gibson, Don Bogard, and Gary Lofgren. Not pictured: Jim Papike.

Above: Larry Taylor, left: Pete Schultz.

Boeing, Google Mars, and the Southwest Meteorite Laboratory were some of the vendors that particpated in the Exhibitor Showcase.

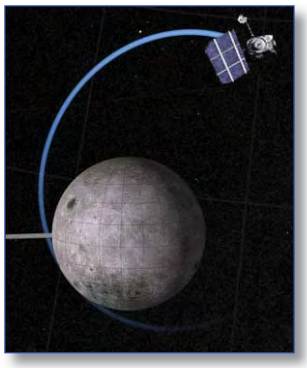
A spacious exhibit hall for posters and large ballrooms for oral sessions facilitated comfortable exchange of ideas and research.

As always, there were plenty of smiling faces, friendly banter, and serious science discussion everywhere you looked.

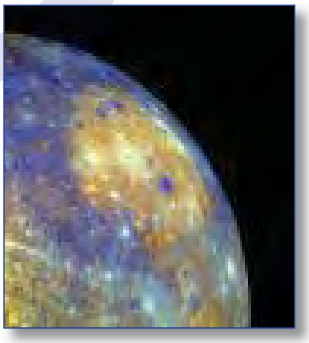
Spotlight on Education

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

Launch a Lunar Event —



On June 18, 2009, NASA successfully launched the Lunar Reconnaissance Orbiter (LRO, *lunar.gsfc.nasa.gov*) and the Lunar Crater Observation and Sensing Satellite (LCROSS, *lcross.arc.nasa.gov*) on their way to the Moon. Scientists and education specialists have an opportunity to engage the public in an impact viewing event on October 9, as LCROSS impacts the Moon and sprays debris into space. Museums, science centers, planetaria, and astronomy clubs will be hosting early morning viewing events, lectures, presentations, and more; contact your local organizations to see how you can be involved.



Discoveries in Planetary Science PowerPoints —

The Education Subcommittee of the AAS Division for Planetary Sciences announces the inaugural release of "Discoveries in Planetary Science" Classroom PowerPoints. These are succinct summaries of discoveries too recent to appear in college textbooks. The first set covers Mars methane, extrasolar planet imaging, the chaotic early solar system, Mars sulfur chemistry, and Mercury volcanism. PowerPoint and PDF files can be downloaded from *dps.aas.org/education/dpsdisc*. Planetary scientists with recent or upcoming results of broad interest are encouraged to submit them for consideration by providing an initial draft using the template provided on the website. For more information, contact Nick Schneider and Dave Brain at dpsdisc@aas.org.

Family Space Day Resources —

The Lunar and Planetary Institute has held monthly events for young children and their families for several years, creating original activities and resources in the process. Those materials are now freely available to download, and include background information for the facilitator, books and websites, fact sheets, and detailed descriptions of the activities and how to conduct them in an informal setting. Educators and scientists interested in holding their own events are welcome to examine these materials for ideas and duplication. Materials are arranged by topic at *www.lpi.usra.edu/education/space_days*.

ASP's 2009 Conference Focuses on the Future —

The Astronomical Society of the Pacific (ASP) invites all Earth and space science educators to attend the 120th anniversary meeting in Millbrae, California, September 12–16, 2009. This year's conference theme is "Science Education and Outreach: Forging a Path to the Future," and will focus on the Year of Science, the International Year of Astronomy, sharing experience and best practices, and establishing new connections and collaborations among science disciplines and each other for future

success in our science education missions. During the conference, provocative plenary discussions will explore several topics:

- IYA: Can We Keep the Party Going?
- Year of Science: Will Science "Speciation" Endanger Science Learning or Enhance it?
- Refining our Practice: Can We Really Make an Impact?
- The Future is Here: Can EPO Navigate the Digital Age?

For conference details and information, visit *www.astrosociety.org/events/meeting.html*.

Solar System Ambassadors —

The Solar System Ambassadors Program is a public outreach program designed to work with motivated volunteers across the nation. These volunteers communicate the excitement of JPL's space exploration missions and information about recent discoveries to people in their local communities. There are now 523 Ambassadors in 50 states, Washington, DC, and Puerto Rico bringing the excitement of space to the public. To learn more or to arrange for a Solar System Ambassador event, go to *www2.jpl.nasa.gov/ambassador*.

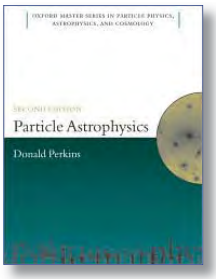
Nominate a Colleague for an AGU Award —

The American Geophysical Union's Excellence in Geophysical Education Award is awarded yearly to recognize and honor an individual, team, or group of individuals who have exhibited a sustained commitment to excellence in geophysical education. The Athelstan Spilhaus Award is to recognize and honor AGU members for enhancement of the public understanding of Earth and space sciences. The deadline for the 2010 awards is October 15, 2009. Nominations may be submitted online at *www.agu.org/inside/spec_eligibility.html*.

2009 Nininger Awards —

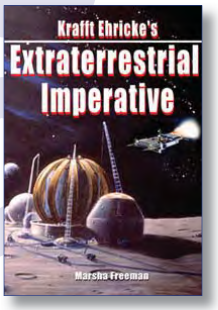
The Center for Meteorite Studies at Arizona State University is accepting applications for the Nininger Meteorite Award for undergraduate and graduate students pursuing research in meteoritical sciences. The Nininger Award recognizes outstanding student achievement in the meteoritical sciences as embodied by an original research paper. Submission deadline is November 13, 2009. More information is available at *meteorites.asu.edu/nininger*.

Books



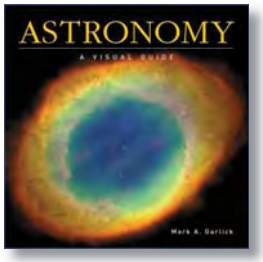
Particle Astrophysics, Second Edition. Donald Perkins. Oxford University Press, 2009. 272 pp., Hardcover, $136.95. *www.oup.com*

Recent years have seen a symbiosis of the fields of elementary particle physics and the astrophysics of the early universe. This text presents the background of the subjects and the latest developments at a level suitable for a physics undergraduate. After introductory chapters on elementary particles and their interactions and role in the expanding universe, the problems and challenges of cosmological asymmetries, dark matter, and dark energy are presented, followed by chapters on the growth of cosmic structure, high-energy cosmic rays, and particle processes in stars. A balance is maintained between theory and experiment and the text is supplemented with over 100 problems, together with answers and model solutions.



Krafft Ehricke's Extraterrestrial Imperative. Marsha Freeman. Apogee Books, 2009. 304 pp., Paperback, $27.95. *www.apogeespacebooks.com*

Readers of this book will gain an insight into one of the most creative minds in the history of space exploration. Ehricke's contributions encompassed details of new and innovative ideas, but he also taught us how to think about the importance and value of space exploration to our society. This book provides an understanding of the early history of the space pioneers, what they helped to accomplish, and how Ehricke's vision of where we should be going can shape the future. At this difficult time, when there are questions about the future path of America's space program, Ehricke's vision — his *Extraterrestial Imperative* — lays out the philosophical framework for why space exploration must be pursued. Readers will find it an imaginative work, and an uplifting story that contains a vast array of reasons why the human race needs to get off planet Earth and explore space. This book is the summation of a lifetime of work encouraging the exploration and development of space.



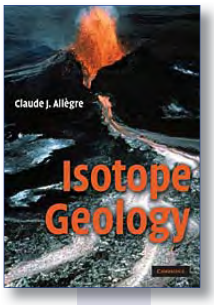
Astronomy: A Visual Guide. Mark A. Garlick. Firefly Books Ltd., 2009. 304 pp., Paperback, $27.95. *www.fireflybooks.com*

This book provides a survey of science's growing understanding of space and includes details of the latest space probes. The most recent photographs from the world's finest observatories and space-based cameras capture the wonder and beauty of the universe. *Astronomy* covers a wide variety of topics including distant stars, planets of the solar system, comets and shooting stars, eclipses, and black holes. The book includes vivid cross-sections of the planets with a concise description and a chart of their relative distance from the Sun, providing at-a-glance information, and a series of monthly sky charts that point out constellations, star clusters, galaxies, nebula, and more. *Astronomy* is a fascinating and easy-to-use illustrated reference for amateur astronomers of all levels.

From Fossils to Astrobiology: Records of Life on Earth and the Search for Extraterrestrial Biosignatures. Edited by Joseph Seckbach and Maud Walsh. Springer, 2008. 548 pp., Hardcover, $299.00. *www.springer.com*

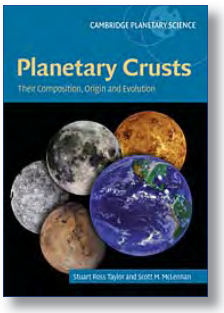
This book reviews developments in paleontology and geobiology that relate to the rapidly developing field of astrobiology. Many traditional areas of scientific study, including astronomy, chemistry, and planetary science, contribute to astrobiology, but the study of the record of life on planet Earth is critical in guiding investigations in the rest of the cosmos. In this book, expert scientists from 15 countries present peer-reviewed, stimulating reviews of paleontological and astrobiological studies. The overviews of established and emerging techniques for studying modern and ancient microorganisms on Earth and beyond will be valuable guides to evaluating biosignatures that could be found in the extraterrestrial surface or subsurface within the solar system and beyond. This volume also provides discussion on the controversial reports of "nanobacteria" in the martian

meteorite ALH 84001. It is a unique volume among astrobiology monographs in focusing on fossil evidence from the geological record and will be valuable to students and researchers alike.



Isotope Geology. Claude J. Allègre. Cambridge University Press, 2008. 512 pp., Hardcover, $80.00. *www.cambridge.org*

Radiogenic and stable isotopes are used widely in the Earth sciences to determine the ages of rocks, meteorites, and archeological objects, and as tracers to understand geological and environmental processes. Isotope methods determine the age of Earth, help reconstruct the climate of the past, and explain the formation of the chemical elements in the universe. This textbook provides a comprehensive introduction to both radiogenic and stable isotope techniques. An understanding of the basic principles of isotope geology is important in a wide range of the sciences: geology, astronomy, paleontology, geophysics, climatology, archeology, and others. Written by one of the world's most respected and best-known geochemists, this full-color textbook will be invaluable for all undergraduate and graduate courses on the topic, and is an excellent reference text for scientists. There are problems at the end of each chapter, with password-protected solutions available to instructors online at the Cambridge University Press website.



Planetary Crusts: Their Composition, Origin and Evolution. Stuart Ross Taylor and Scott McLennan. Cambridge University Press, 2009, 400 pp., Hardcover, $150.00. *www.cambridge.org*

This is the first book ever published to explain how and why solid planets and satellites develop crusts. Written by two leading authorities on the subject, it presents a geochemical and geological survey of the crusts of the Moon, Mercury, Venus, Earth, Mars, the asteroid Vesta, and several satellites such as Europa, Ganymede, and Callisto. After describing how solar system bodies are formed, the authors compare the different planetary crusts and discuss current controversies on the subject. They introduce the theory of stochastic processes dominating crustal development, and debate the possibility of Earth-like planets existing elsewhere in the cosmos. Extensively referenced and annotated, this book presents an up-to-date survey of the scientific problems of crustal development, and is a key reference for researchers and students in geology, geochemistry, planetary science, astrobiology, and astronomy.

DVDs

Developing Project Apollo. Produced and directed by Mark Gray, 2009, one disc. $19.99. *www.spacecraftfilms.com*

This audiovisual collection contains unique material surrounding the development of the Apollo Manned Lunar Landing Project. These rare programs provide a unique glimpse into the development of the program at Johnson Space Center in the mid 1960s. The programs tend to be project, operational, and spacecraft specific. Running time over 3.5 hours.

Field Trip to the Moon. Produced by NASA, 2007, one disc, for grades 5–8. $12.00. ***corecatalog.nasa.gov***

Field Trip to the Moon is a virtual journey using NASA engineering models and scientific data. Like NASA's astronauts, viewers are faced with the challenges and excitement of launching from Earth's surface and journeying to the Moon. Along the way, they discover the differences between the Earth and the Moon, and what makes Earth unique and habitable. The DVD features an introduction, the feature (a complete journey from launch to Moon orbit and landing), and extras. NASA Central Operation of Resources for Educators and the American Museum of Natural History have worked together to provide educators with toolboxes, which will bring this "field trip" to life. These toolboxes match up with each of the six science-based team explorations: ecosystem, engineering, geology, habitat, medical, and navigation. Related guides are available online.

For Kids!!!

Space. Produced by Twin Sisters Productions. Audio CD and 24-page activity book, $12.99. *www.twinsisters.com*

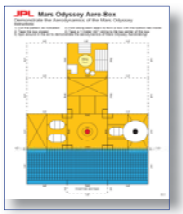
This music CD contains fun, factual songs for the young astronaut who dreams of becoming a space traveler! Kids will learn about the history of space travel, the possibility of living in space someday, weightlessness, satellites, what's required of an astronaut, and more. The set includes a music CD and 24-page activity book with lyrics, diagrams, a quiz, and a letter from a NASA researcher about working at NASA. This set has been approved and recommended by NASA. For ages 4–9.

Solar System Styrofoam Science Kit. From Hygloss. $16.99. *www.hygloss.com*

This Solar System Styrofoam Science Kit is perfect for an individual project or small group activity. Students can build their own solar system by following the simple instructions included. This kit is packaged in attractive and sturdy plastic cylinder for convenient storage. For grades 4–8.

Cool Stuff Exploded. Chris Woodford. DK Publishing, 2008. 256 pages, Hardcover, $24.99. *us.dk.com*

This supercool technology book deconstructs — or literally *explodes* — everyday objects so readers can see exactly how they work. Beautifully photographed spreads show a piece-by-piece breakdown of cell phones, computers, cars — even a future space plane and spacesuit — detailing how each part works and how they all fit together as a whole. This unique look at the items we use every day brings science, technology, and wonder to the fore, giving us all a great appreciation for how our twenty-first-century world works. Set into the cover is a CD-ROM containing animations of the "exploded" views featured in the book. For ages 9–12.



Space Exploration Paper Models. From the NASA Solar System Exploration website. *solarsystem.nasa.gov/kids/papermodels.cfm*

Right now, a bunch of super tough robots are out there exploring our solar system. You can build paper versions of many of them right here on Earth. Paper modeling — or card modeling — is the art of constructing things with only colored, cut, and folded pieces of paper. To help in constructing each model, you will need Adobe Reader to print the instructions and model parts. (A link to adobe.com is provided with each model.) Remember, spacecraft construction is a team activity. Get some friends and an adult to pitch in on the mission. Choose a ship to start your space fleet. Spacecraft include Cassini, Galileo, Lunar Prospector, Mars 2001 Odyssey, and Mars Express.

Moon Landing. Richard Platt and David Hawcock. Candlewick Press, 2008. 10 pages, Hardcover, $29.99. *www.candlewick.com*

Trace the history of people's fascination with the Moon — and the scientific developments that led to a ground-breaking mission — in an out-of-this-world novelty book marking the first Moon landing. Acclaimed author Richard Platt focuses on humankind's dreams of traveling to the Moon, the race to conquer space, the technology needed to reach the Moon and sustain the astronauts in space, and the Moon landing itself. Recreating the excitement of the expedition are extraordinary popups depicting a rocket, the lunar module, a spaceship, and a spectacular spherical Moon, while booklets and flaps offer readers a wealth of intriguing facts. For ages 8 and up.

July

5–10 **Gordon Conference on the Origin of Solar Systems**, South Hadley, Massachusetts. *www.grc.org/programs.aspx?year=2009&program=origins*

6–8 **A Joint European/Japanese Workshop on the SPICA Mission**, Oxford, United Kingdom. *www.sstd.rl.ac.uk/spica/index.html*

6–8 **First Meeting of the Planetary Decadal Survey Steering Group**, Washington, DC. *www7.nationalacademies.org/ssb/SSEdecadal2011.html*

6–11 **Seventh International Conference on Geomorphology (ANZIAG)**, Melbourne, Australia. *www.geomorphology2009.com/*

12–18 **Fifth NAIC/NRAO Single-Dish Summer School**, Arecibo, Puerto Rico. *www.naic.edu/~astro/sdss5/*

13–14 **Computational Astrophysics**, Princeton, New Jersey. *www.sns.ias.edu/pitp/*

13–18 **72nd Annual Meeting of the Meteoritical Society**, Nancy, France. *www.lpi.usra.edu/meetings/metsoc2009/*

15–17 **2009 Europa Jupiter System Mission Instrument Workshop**, Laurel, Maryland. *opfm.jpl.nasa.gov/europajupitersystemmissionejsm/2009ejsminstrumentworkshop2i/*

19–29 **Joint Assembly Meeting of IAMAS, IAPSO, and IACS (MOCA-09)**, Montreal, Canada. *www.iamas-iapso-iacs-2009-montreal.ca/e/99-home_e.shtml*

20–24 **13th International Workshop on Low Temperature Detectors**, Stanford, California. *ltd13.stanford.edu/*

20–24 **2009 Sagan Summer Workshop on Exoplanetary Atmospheres**, Pasadena, California. *nexsci.caltech.edu/workshop/2009/index.shtml*

20–24 **From Core to Crust: Towards an Integrated Vision of Earth's Interior**, Trieste, Italy. *cdsagenda5.ictp.it/full_display.php?email=0&ida=a08171*

20–24 **New Technologies for Probing the Diversity of Brown Dwarfs and Exoplanets**, Shanghai, China. *web.mac.com/triple_binary/BD/Welcome.html*

21–23 **Second Annual NLSI Lunar Science Conference**, Moffett Field, California. *lunarscience2009.arc.nasa.gov*

21–24 **Third International Workshop on Mars Polar Energy Balance and the CO_2 Cycle**, Seattle, Washington. *www.lpi.usra.edu/meetings/mpeb2009*

27–28 **The New Martian Chemistry Workshop**, Medford, Massachusetts. *www.lpi.usra.edu/meetings/marschem2009*

27–31 **Magnetospheres of the Outer Planets 2009**, Cologne, Germany. *mop2009.uni-koeln.de/*

August

2–7 **42nd IUPAC Congress: Chemistry Solutions**, Glasgow, Scotland. *www.rsc.org/ConferencesAndEvents/RSCConferences/IUPAC2009/*

3–7 **IAU Symposium 263: Icy Bodies in the Solar System,** Rio de Janeiro, Brazil. *www.astronomia.edu.uy/congresos/symp263/*

3–14 **IAU XXVII General Assembly**, Rio de Janeiro, Brazil. *www.astronomy2009.com.br/*

5–6 **Workshop on Robots Supporting Human Science and Exploration (OSEWG 2009)**, Houston, Texas. *www.lpi.usra.edu/meetings/osewg2009*

10–13 **Astronomy and Civilization**, Budapest, Hungary. *www.konkoly.hu/AC2009/*

11–15 **Sixth Annual Meeting and Exhibition of the Asia Oceania Geosciences Society (AOGS 2009)**, Suntec City, Singapore. *www.asiaoceania.org/aogs2009/index.asp*

17–21 **Dynamics of Outer Planetary Systems, Edinburgh**, United Kingdom. *www.newton.ac.uk/programmes/DDP/ddpw03.html*

17–21 **The Dynamics of Discs and Planets**, Cambridge, United Kingdom. *www.newton.ac.uk/programmes/DDP/ddpw01.html*

23–29 **International Association of Geomagnetism and Aeronomy (IAGA) 11th Scientific Assembly**, Sopron, Hungary. *www.iaga2009sopron.hu/*

24–26 **International Conference on Space Technology**, Thessaloniki, Greece. *www.icspacetechnology.com/*

24–27 **Conference on Characterization and Radiometric Calibration for Remote Sensing**, Logan, Utah. *www.spacedynamics.org/conferences/calcon/*

27–29 **Workshop on the Microstructure of the Martian Surface**, Copenhagen, Denmark. *www.lpi.usra.edu/meetings/marsmicro2009*

30–Sept 5 **Natural Dynamos**, Stará Lesná, Slovakia. *rebel.ig.cas.cz/Tatry2009/*

31–Sept 5 **Ninth Ukrainian Conference on Space Research**, Yevpatoria, Ukraine. *www.nkau.gov.ua/ukrspace09/index.html*

September

1–4 **Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS)**, Maui, Hawaii. *www.amostech.com/index.php*

12–16 **Science Education and Outreach: Forging a Path to the Future: The 120th Anniversary Meeting of the Astronomical Society of the Pacific**, Millbrae, California. *www.astrosociety.org/events/meeting.html*

13–18 **European Planetary Science Congress 2009 (EPSC 2009),** Potsdam, Germany. *meetings.copernicus.org/epsc2009/*

14–18 **Pathways Towards Habitable Planets,** Barcelona, Spain. *www.pathways2009.net/*

15–17 **Mars Dust Cycle Workshop**, Moffett Field, California. *humbabe.arc.nasa.gov/MarsDustWorkshop/DustHome.html*

20–23 **Sedimentology and Stratigraphy in the Inner and Outer Solar System,** Alghero, Italy. *europlanet.cesr.fr/pages/evt/docs/Calendar_September20-23_2008_IAS.pdf*

21–25 **International Conference on Asteroid-Comet Hazard 2009**, St. Petersburg, Russia. *quasar.ipa.nw.ru/conference/ach2009/*

21–25 **Deciphering the Universe Through Spectroscopy: The 82nd Annual Meeting of the Astronomische Gesellschaft (AG),** Potsdam, Germany. *www.aip.de/AG2009/*

24–27 **International Meteor Conference 2009,** Porec, Croatia. *www.imo.net/imc2009/*

28–30 **Planetesimal Formation**, Cambridge, United Kingdom. *www.newton.ac.uk/programmes/DDP/ddpw02.html*

October

4–9 **41st Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society**, Fajardo, Puerto Rico. *dps09.naic.edu/*

12–14 **Geological Mapping of Mars: A Workshop on New Concepts and Tools**, Tuscany, Italy. *www.irsps.unich.it/education/mapping09/*

12–16 **60th International Astronautical Congress (IAC)**, Daejeon, South Korea. *www.iac2009.kr/*

16–18 **2nd Halifax Meeting on Computational Astrophysics**, Halifax, Canada. *www.smu.ca/partners/ICA/*

18–21 **Geological Society of America Annual Meeting**, Portland, Oregon. *www.geosociety.org/meetings/2009/*

19–23 **Towards Other Earths: Perspectives and Limitations in the ELT Era**, Porto, Portugal. *www.astro.up.pt/investigacao/conferencias/toe2009/*

28–30 **Space Resources Roundtable XI**, Golden, Colorado. *www.isruinfo.com/*

November

3–6 **From Circumstellar Disks to Planetary Systems**, Garching, Germany. *www.eso.org/sci/meetings/disks2009/index.html*

9–10 **The First Arab Impact Cratering and Astrogeology Conference** (*with field trip on Nov. 11*), Amman, Jordan. *aicac.jga.org.jo/main1/*

16–19 **Annual Meeting of the Lunar Exploration Analysis Group**, Houston, Texas. *www.lpi.usra.edu/meetings/leag2009*

23–27 **Mathematics and Astronomy: A Joint Long Journey**, Madrid, Spain. *www.astromath2009.com/welcome.html*

December

14–18 **AGU Fall Meeting**, San Francisco, California. *www.agu.org/meetings*

15 **Human-Tended Suborbital Science Workshop**, San Francisco, California. *suborbitalex.arc.nasa.gov/*

February 2010

5–10 **2010 NSBE Aerospace Systems Conference**, Los Angeles, California. *www.nsbe-asc.org/*

March

1–5 **41st Lunar and Planetary Science Conference (LPSC 2010)**, The Woodlands, Texas. *www.lpi.usra.edu/meetings/lpsc2010*

29–Apr 2 **Exoplanets Rising: Astronomy and Planetary Science at the Crossroads**, Santa Barbara, California. *www.kitp.ucsb.edu/activities/auto/?id=983*