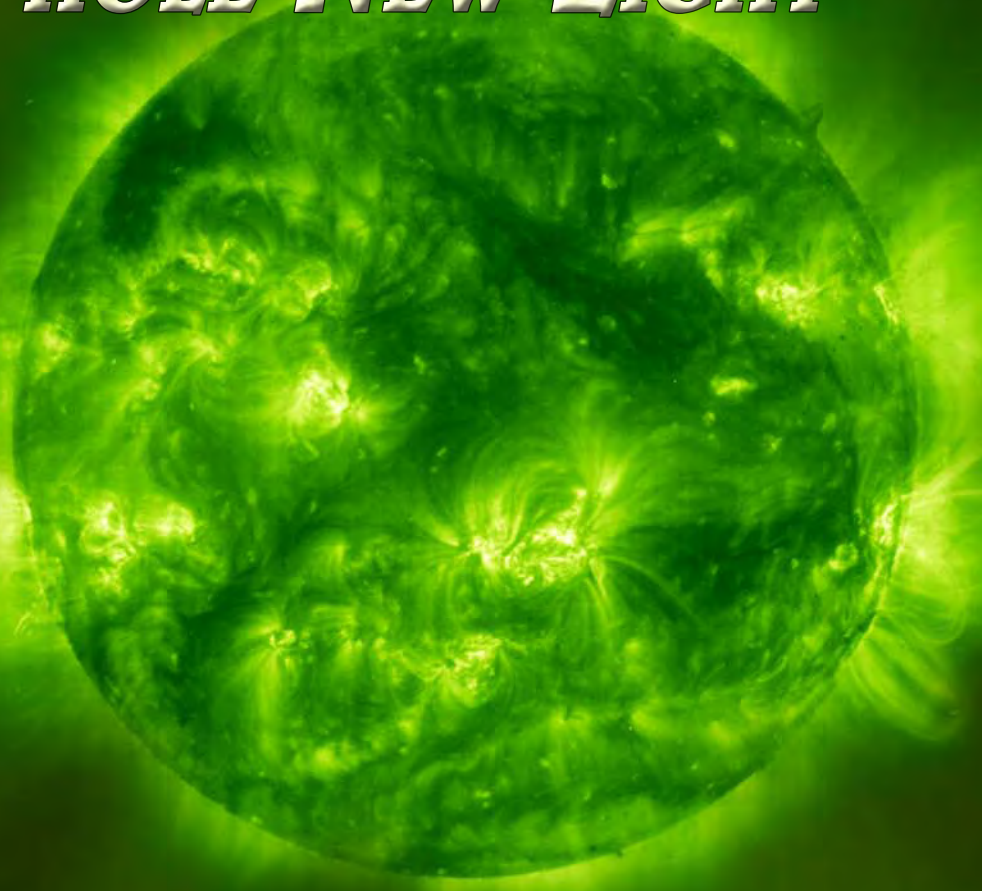
Seeing Our Sun in a Whole New Light



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Lunar and Planetary Information

BULLETIN

Lunar and Planetary Institute — Universities Space Research Association

May 2007
Issue 110

www.lpi.usra.edu/lpib

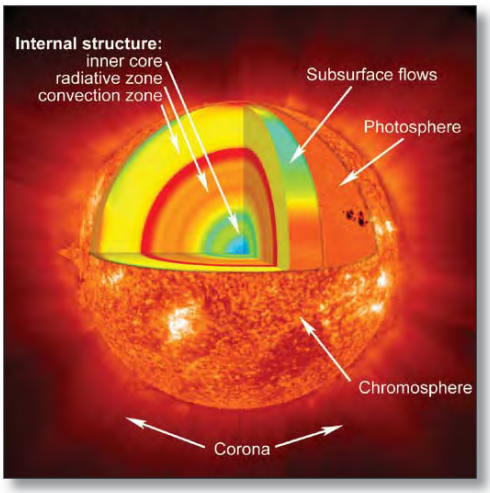
Seeing Our Sun in a Whole New Light

— Rachel C. F. Lentz, Freelance Science Writer

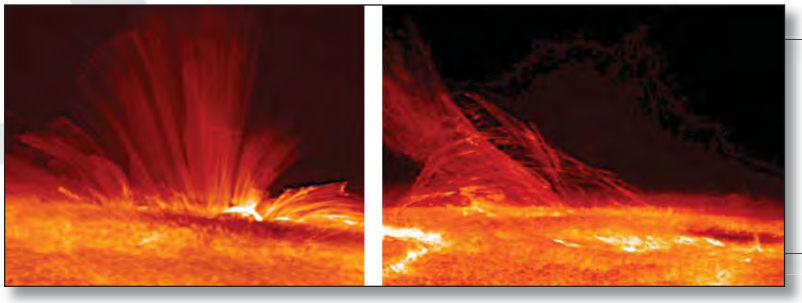
The Sun is the source of all life and energy on this planet, but it can also be a great source of mystery and mayhem. NASA has recently launched two new solar observatories — Hinode and STEREO — to view the Sun in novel ways in an effort to unravel some key mysteries and prevent some disastrous mayhem. Both spacecraft systems are focusing on the outer layers of the Sun — the chromosphere and the corona — to examine the processes in these layers associated with massive solar explosions called coronal mass ejections (CMEs). These solar storms can wreak havoc on our unprotected satellites and orbital instruments, so the better we understand the processes that cause the storms, the better we can predict them and protect ourselves. Already, these missions have begun to reveal amazing new information about the Sun, and have shown scientists there is a lot more to learn.

Hinode (meaning "sunrise" in Japanese) is an international collaboration between the space agencies of Japan, the United Kingdom and Europe, and NASA. It was launched on September 23, 2006, into a polar orbit (running from pole to pole) to give nearly continuous viewing of the Sun. Hinode was designed as a successor to Yohkoh, a previous Japanese solar mission that examined the solar atmosphere at X-ray and gamma-ray wavelengths. Hinode will also look in the X-ray wavelengths, but adds views in the visible spectrum and at extreme ultraviolet wavelengths. In addition, its telescopes are designed to operate at much higher resolutions than the preceding mission. For example, the optical telescope can resolve features 0.2 arcseconds across. This is the equivalent of resolving a feature 50 centimeters (~20 inches) across back on Earth. Hinode's primary mission is to examine the relationship and interactions between the Sun's magnetic fields and its outermost layer, the corona. It is also equipped to look at multiple atmospheric layers at once, to build up a three-dimensional picture of ongoing processes, and to illustrate how events in one layer may affect the conditions in another layer.

The Sun's outer reaches are divided into three primary layers: the photosphere, the chromosphere, and the corona. The photosphere is the visible surface of the Sun that radiates light and energy. The chromosphere is the source of ultraviolet (UV) radiation from the Sun and is much hotter than the underlying photosphere (up to 100,000°C compared with only about 6000°C at the Sun's surface). Until recent videos from Hinode, this layer was thought to be fairly static and motionless, but is now recognized as a roiling confusion of heated gas and moving magnetic field lines. The corona is essentially the diffuse extension of the Sun's atmosphere into space. It is the source of the charged particles (or plasma) that blow out across the solar system, called the solar wind. Even more than the chromosphere, the corona is far hotter than the Sun's surface, reaching temperatures as high as several million degrees!



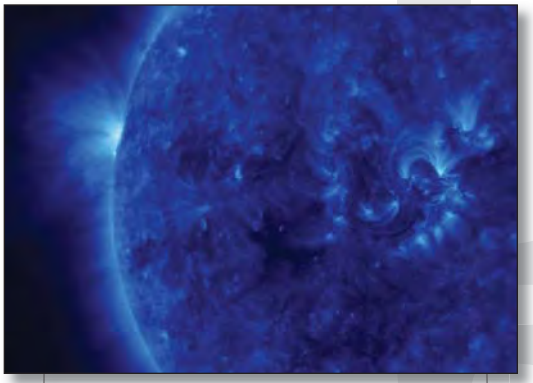
This incredible increase in temperature out to the corona is one of the big mysteries of the Sun, and one that Hinode is specifically hoping to address. A current hypothesis to explain the high temperatures is that complex interactions between magnetic field lines abruptly release bursts of stored energy, heating the surrounding gases.



Hinode images from the Solar Optical Telescope showing the intricate and filamentous structures drawn by plasma in the Sun's chromosphere. Charged particles travel along magnetic field lines that arc up from, and back down to, the underlying photosphere. Image courtesy of Hinode JAXA/NASA.

The magnetic fields are also a target for Hinode to study, particularly since they are intimately related to the generation of the most impressive solar phenomena, solar flares and coronal mass ejections (CMEs). When particularly large bursts of energy are generated, massive plasma ejections are accelerated to very high speeds (nearly the speed of light!) and flung out across the solar system. CMEs can pose serious dangers to our orbiting satellites, planetary spacecraft, landbased technologies (GPS, cell phones, etc.), and particularly to unprotected astronauts in orbit, on the Moon's surface, or even en route to Mars. This is where the second new solar instrument comes in.

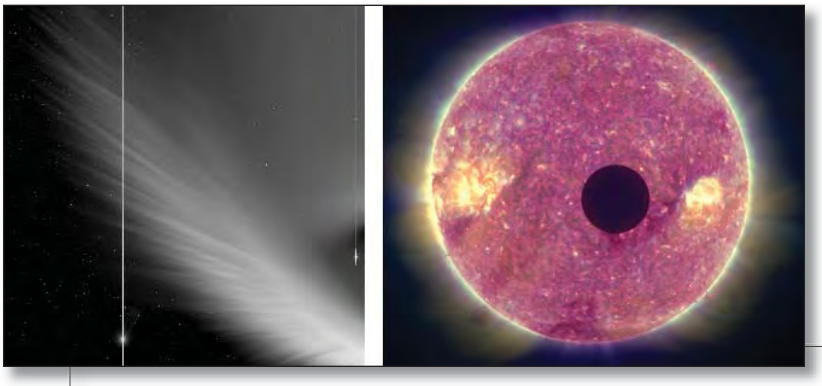
The Solar TErrestrial RElations Observatory, or STEREO, is actually composed of two nearly identical spacecraft, STEREO-A and STEREO-B. The two were launched together on one rocket on October 25, 2006, but flung to different locations along the Earth's orbital path by lunar gravity boosts. One lies a million miles ahead of Earth (A) and one travels a million miles behind Earth (B). (A is actually moving a little faster than B, so the observatories will separate by about 45°, or about 73 million miles, each year.) Each craft is laden with identical instrumentation to image the Sun and its corona in extreme UV, track radio bursts, and measure the composition and distribution of solar energetic particles from the solar wind and from CMEs.



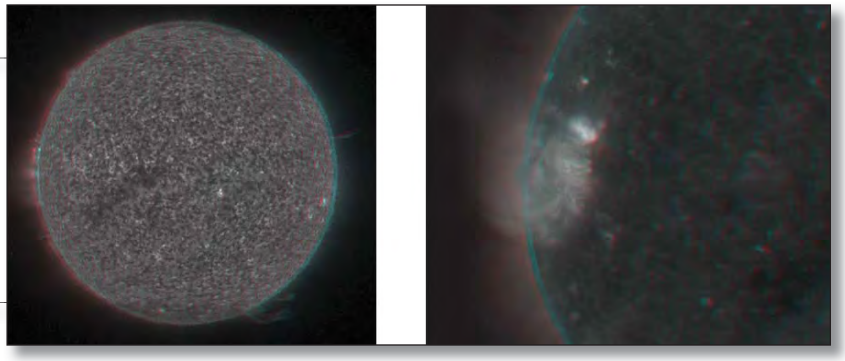
Two-dimensional image from STEREO mission showing highly active regions of the Sun. Image courtesy of STEREO/NASA.

The unique aspect of this mission is the separation of the two craft. By overlapping two images from different points of view, scientists can create three-dimensional (3D) stereo images, just as your brain creates a 3D view of the world from your two eyes. This enhanced imaging from STEREO will allow scientists an unprecedented view of the structure and evolution of activity in the Sun's upper atmosphere, particularly of CMEs as they emanate from the Sun and travel to Earth. The primary goal of this mission is to improve not only our understanding of these massive solar storms, but also to increase the accuracy of arrival time predictions to a couple of hours, rather than the current half-day timeframe. With sufficient warning of oncoming storms, dangerous consequences to both people and electronic hardware in space could be avoided.

The STEREO spacecraft only recently maneuvered into position, and from January through March of this year, during instrument calibration, they sent back spectacular (but regular two-dimensional) images of solar prominences, the details of a comet tail, and a lunar transit, illustrating the tantalizing possibilities for this innovative mission. Finally, at the end of April, STEREO returned the first 3D images, showing in fabulous depth and detail the activity on our Sun's surface.



Two images from January when STEREO was still calibrating. Left, the tail of Comet McNaught was caught by STEREO showing dazzling filigree on its very close approach to the Sun. (Bright points causing vertical saturation lines are Venus and Mercury.) Right, the off-angle position of the STEREO spacecraft allowed a unique view of our Moon crossing the face of the Sun (called a transit). Image courtesy of STEREO/NASA.



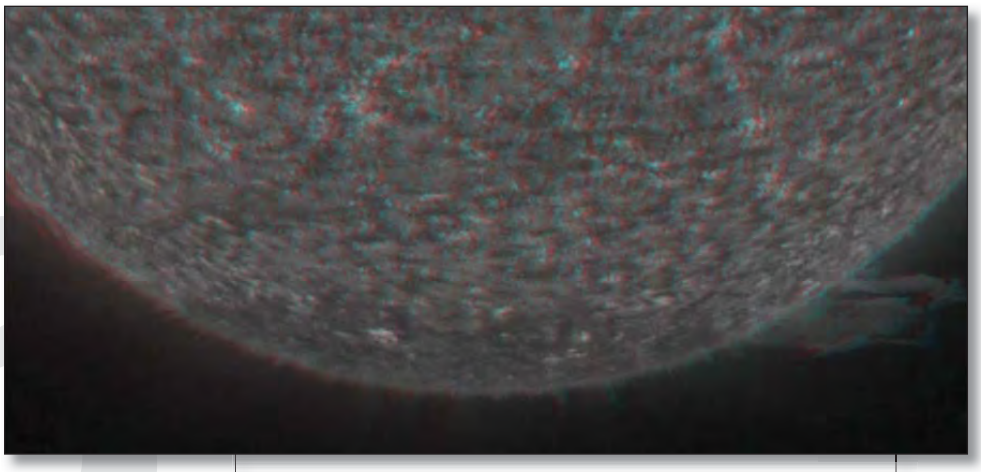
The first 3D images of our Sun from the STEREO mission illustrating activity at different temperature ranges. Left: A full-disk image showing multiple regions of activity at near 1,000,000°. Right: A close-up of a particularly active region in the 2,500,000° temperature range. (View with 3D glasses for proper stereo effect.) Image courtesy of STEREO/NASA.

With new views like these of the Sun, in 3D from STEREO and at remarkably high resolution from Hinode, solar scientists are already gaining new insights into how the Sun's chromosphere and corona interact to produce such massive explosive activity as CMEs. This new knowledge will someday help to protect our technology and space travelers when weather forecasters will be able to warn us of impending solar storms as routinely as terrestrial thunderstorms.

Hinode is a collaborative mission led by the Japan Aerospace Exploration Agency and includes the European Space Agency and Britain's Particle Physics Astronomy Research Council. The National Astronomical Observatory of Japan, Tokyo, developed the Solar Optical Telescope, and developed the X-ray Telescope in collaboration with the Smithsonian Astrophysical Observatory of Cambridge, Massachusetts. The NASA Marshall Space Flight Center manages the development of the scientific instrumentation provided for the mission by NASA, industry and other federal agencies.

STEREO is the third mission in NASA's Solar Terrestrial Probes Program. STEREO is sponsored by NASA's Science Mission Directorate, Washington, DC. The NASA Goddard Science and Exploration Directorate manages the mission, instruments, and science center. The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, designed and built the spacecraft and is operating them for NASA during the mission. The STEREO instruments were designed and built by scientific institutions in the U.S., United Kingdom, France, Germany, Belgium, Netherlands, and Switzerland.

For more information, visit *www.nasa.gov/mission_pages/solar-b/index.html*, *solar-b.nao.ac.jp/index_e.shtml*, and *www.nasa.gov/mission_pages/stereo/main/index.html*.



Details of the Sun's south pole in 3D showing a burst of cooler material (60,000°–80,000°) shooting from the chromosphere surface into space. Image courtesy of STEREO/NASA.

Pluto-Bound New Horizons Provides New Look at Jupiter System

NASA's New Horizons spacecraft has provided new data on the Jupiter system, stunning scientists with never-before-seen perspectives of the giant planet's atmosphere, rings, moons, and magnetosphere. New Horizons came to within 1.4 million miles of Jupiter on February 28, 2007, using the planet's gravity to trim three years from its travel time to Pluto. For several weeks before and after this closest approach, the piano-sized robotic probe trained its seven cameras and sensors on Jupiter and its four largest moons, storing data from nearly 700 observations on its digital recorders and gradually sending that information back to Earth.

"Aside from setting up our 2015 arrival at Pluto, the Jupiter flyby was a stress test of our spacecraft and team, and both passed with very high marks," said Science Mission Directorate Associate Administrator and New Horizons Principal Investigator Alan Stern. "We'll be analyzing this data for months to come; we have collected spectacular scientific products as well as evocative images."

Images include the first close-up scans of the Little Red Spot, Jupiter's second-largest storm, which formed when three smaller storms merged during the past decade. The storm, about half the size of Jupiter's larger Great Red Spot and about 70% of Earth's diameter, began turning red about a year before New Horizons flew past it. Scientists will search for clues about how these systems form and why they change colors in their close observations of materials spinning within and around the nascent storm.

"This is our best look ever of a storm like this in its infancy," said Hal Weaver, New Horizons project scientist from the Johns Hopkins University Applied Physics Laboratory (APL). APL built and operates the New Horizons spacecraft. "Combined with data from telescopes on and around Earth taken at the same time New Horizons sped past Jupiter, we're getting an incredible look at the dynamics of weather on giant planets."

Under a range of lighting and viewing angles, New Horizons also grabbed the clearest images ever of the tenuous jovian ring system. In them, scientists spotted a series of unexpected arcs and clumps of dust, indicative of a recent impact into the ring by a small object. Movies made from New Horizons images also provide an unprecedented look at ring dynamics, with the tiny inner moons Metis and Adrastea appearing to shepherd the materials around the rings.

"We're starting to see that rings can evolve rapidly, with changes detectable during weeks and months," said Jeff Moore, New Horizons Jupiter Encounter science team lead from NASA Ames Research Center. "We've seen similar phenomena in the rings of Saturn."

Of Jupiter's four largest moons, the team focused much attention on volcanic Io, the most geologically active body in the solar system. New Horizons' cameras captured pockets of bright, glowing lava scattered across the surface; dozens of small, glowing spots of gas; and several fortuitous views of a sunlit umbrella-shaped dust plume rising 200 miles into space from the volcano Tvashtar, the best images yet of a giant eruption from the tortured volcanic moon. The timing and location of the spacecraft's trajectory also allowed it to spy many of the mysterious, circular troughs carved onto the icy moon Europa. Data on the size, depth, and distribution of these troughs, discovered by the Jupiter-orbiting Galileo mission, will help scientists determine the thickness of the ice shell that covers Europa's global ocean.

Already the fastest spacecraft ever launched, New Horizons reached Jupiter 13 months after lifting off from Cape Canaveral Air Force Station in January 2006. The flyby added 9000 miles per hour, pushing New Horizons past 50,000 miles per hour and setting up a flight by Pluto in July 2015.

"We can run simulations and take test images of stars, and learn that things would probably work fine at Pluto," said John Spencer, deputy lead of the New Horizons Jupiter Encounter Science Team, Southwest Research Institute, Boulder. "But having a planet to look at and lots of data to dig into tells us that the spacecraft and team can do all these amazing things. We might not have explored the full capabilities of the spacecraft if we didn't have this real planetary flyby to push the system and get our imaginations going."

More data are to come, as New Horizons completes its unprecedented flight down Jupiter's long magnetotail, where it will analyze the intensities of Sun-charged particles that flow hundreds of millions of miles beyond the giant planet. To view the new images and learn more about the New Horizons mission, visit *www.nasa.gov/newhorizons*.

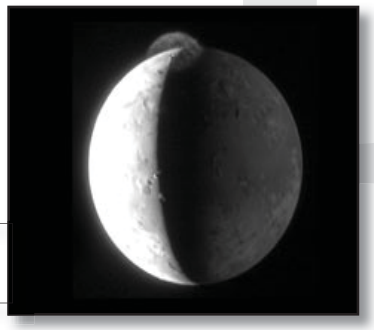


Image of Jupiter's moon, Io, as seen by the New Horizons spacecraft. A volcanic plume can be seen at the top of the moon. Credit: NASA/JHUAPL.

NASA Antenna Cuts Mercury to Core, Solves 30-Year Mystery

Researchers working with high-precision planetary radars, including the Goldstone Solar System Radar of NASA's Jet Propulsion Laboratory (JPL), have discovered strong evidence that the planet Mercury has a molten core. The finding explains a more than three-decade-old planetary mystery that began with the flight of JPL's Mariner 10 spacecraft. The research appears in a recent issue of the journal *Science*.

Launched in November 1973, Mariner 10 made three close approaches to Mercury in 1974 and 1975. Among its discoveries was that Mercury had its own weak magnetic field — about 1% as strong as that found on Earth.

"Scientists had not expected to find a magnetic field at Mercury," said Professor Jean-Luc Margot of Cornell University, leader of the research team. "Planetary magnetic fields are associated with molten cores, and the prevailing theory was the planet was too small to have a molten core."

Many believed the Mercury mystery would only be resolved if and when a spacecraft landed on its aggressively toasty surface. Then, in 2002, scientists began pointing some of the most powerful antennas on our planet at Mercury in an attempt to find the answer.

"On 18 separate occasions over the past five years, we used JPL's Goldstone 70-meter [230-foot] antenna to fire a strong radar signal at Mercury," said Planetary Radar Group Supervisor Martin Slade of JPL, a co-author of the paper. "Each time, the radar echoes from the planet were received about 10 minutes later at Goldstone and another antenna in West Virginia."

Measuring the echo of particular surface patterns from the surface of Mercury and how long they took to reproduce at both Goldstone and the Robert C. Byrd Green Bank Telescope in West Virginia allowed scientists to calculate Mercury's spin rate to an accuracy of one-thousandth of a percent. The effect was also verified with three more independent radar observations of Mercury transmitted from the National Science Foundation's Arecibo Observatory in Puerto Rico.

With these data the science team was able to detect tiny twists in Mercury's spin as it orbited the Sun. These small variations were double what would be expected for a completely solid body. This finding ruled out a solid core, so the only logical explanation remaining was that the core — or at the very least the outer core — is molten and not forced to rotate along with its shell. Maintaining a molten core over billions of years requires that it also contain a lighter element, such as sulfur, to lower the melting temperature of the core material.

Mercury still has its share of mysteries. Some may be solved with the NASA spacecraft MESSENGER, launched in 2004 and expected to make its first Mercury flyby in 2008. The spacecraft will then begin orbiting the planet in 2011. "It is our hope that Messenger will address the remaining questions that we cannot address from the ground," said Margot.

Artist's impression of the MESSENGER spacecraft in orbit at Mercury. Scientists hope that the mission will answer many questions about the planet that cannot be resolved from Earth. Credit: NASA/JHUAPL/Carnegie Institution of Washington.

Mars Rover Churns Up Questions with Sulfur-rich Soil

Some bright martian soil containing lots of sulfur and a trace of water intrigues researchers who are studying information provided by NASA's Spirit rover. "This material could have been left behind by water that dissolved these minerals underground, then came to the surface and evaporated, or it could be a volcanic deposit formed around ancient gas vents," said Ray Arvidson of Washington University, St. Louis. He is the deputy principal investigator for NASA's twin Mars rovers, Spirit and Opportunity.

Determining which of those two hypotheses is correct would strengthen understanding of the environmental history of the Columbia Hills region that Spirit has been exploring since a few months after landing on Mars in January 2004. However, investigating the bright soil presents a challenge for the rover team, because the loose material could entrap the rover. The bright white and yellow material was hidden under a layer of normal-looking soil until Spirit's wheels churned it up while the rover was struggling to cross a patch of unexpectedly soft soil nearly a year ago. The right front wheel had stopped working a week earlier. Controllers at NASA's Jet Propulsion Laboratory were trying to maneuver the rover backward, dragging that wheel, to the north slope of a hill in order to spend the southern-hemisphere winter with solar panels tilted toward the Sun.

Because of the difficulty crossing that patch, informally named "Tyrone," the team chose to drive Spirit to a smaller but more accessible slope for the winter. Spirit stayed put in its winter haven for nearly seven months. Tyrone was one of several targets Spirit examined from a distance during that period, using an infrared spectrometer to check their composition. The instrument detected small amounts of water bound to minerals in the soil.

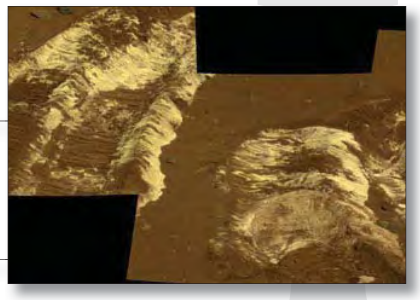
The rover resumed driving in late 2006 when the martian season brought sufficient daily sunshine to the solar panels. Some of the bright soil from Tyrone was dragged to the winter site by the right front wheel, and Spirit spent some time measuring the composition and mineralogy of these materials. The material is sulfur-rich and consists of sulfate salts associated with iron and likely calcium. "These salts could have been concentrated by hydrothermal liquid or vapor moving through the local rocks," said rover science team member Albert Yen, a geochemist at JPL. Two other patches of bright soil uncovered by Spirit before Tyrone were also sulfur-rich, but each had similarities to local rock compositions that were different at the three sites, suggesting localized origins.

Halfway around Mars, Opportunity is exploring clockwise around "Victoria Crater," a bowl about 800 meters (half a mile) across. Cliff-like promontories alternate with more gradually sloped alcoves around the scalloped rim. The impact that dug the crater exposed layers that had been buried. "The images are breathtaking," said Steve Squyres of Cornell University, principal investigator for the rovers. "Every promontory we've seen has the kinds of layering expected for ancient wind-blown sand deposits."

The layers consist of sulfate-rich sandstone similar to other bedrock Opportunity has been finding in Mars' Meridiani region for more than three years. The minerals come from a wet period in the region's ancient past. While exploring Victoria's rim with Opportunity, researchers have been on the lookout for rocks that might have been tossed out from layers deeper and older than the sulfates.

"We found one group of cobbles that were clearly more resistant to erosion than the sulfate blocks thrown out onto the rim," Squyres said. "We checked the composition of one that we called Santa Catarina. Our suspicion now is that Santa Catarina is a piece of a meteorite." That would be the fifth meteorite found by the rovers.

More than three years into what was planned as a three-month mission on Mars, both Spirit and Opportunity remain in good health, although with signs of aging. "The team has learned how to drive Spirit very well with just five wheels," said JPL's John Callas, rover project manager. "We could accomplish longer drives if there were more energy, but Spirit's solar panels have gotten really dusty. We would welcome another wind-related cleaning event." It's about the same time of year on Mars now as it was when winds blew dust off Spirit and its solar panels in 2005, increasing energy output.



While driving eastward toward the northwestern flank of "McCool Hill," the wheels of the Spirit rover churned up the largest amount of bright soil discovered so far in the mission. This image shows the strikingly bright tone and large extent of the materials uncovered. Credit: NASA/JPL-Caltech/Cornell.

Mars Rover Finds Evidence of Ancient Volcanic Explosion

Mars Exploration Rover Spirit has discovered evidence of an ancient volcanic explosion at "Home Plate," a plateau of layered bedrock approximately 2 meters (6 feet) high within the "Inner Basin" of Columbia Hills, at the rover's landing site in Gusev Crater. This is the first explosive volcanic deposit identified with a high degree of confidence by Spirit or its twin, Opportunity.

"There is strong evidence that those layers are from a volcanic explosion," said Steve Squyres of Cornell University, principal investigator for the rovers' science instruments. The findings about volcanic activity are reported in a paper published in the May 4 issue of the journal *Science*.

Evidence shows the area near Home Plate is dominated by basaltic rocks. "When basalt erupts, it often does so as very fluid lava, rather than erupting explosively," Squyres said. "One way for basaltic lava to cause an explosion is for it to come into contact with water — it's the pressure from the steam that causes it to go boom."

Scientists suspect that the explosion that formed Home Plate may have been caused by an interaction of basaltic lava and water. "When you look at composition of the rocks in detail, there are hints that water may have been involved," Squyres said. One example is the high chlorine content of the rocks, which might indicate that basalt had come into contact with a brine.

One of the strongest pieces of evidence for an explosive origin for Home Plate is a "bomb sag" preserved in layered rocks on the lower slopes of the plateau. Bomb sags form in volcanic explosions on Earth when rocks ejected skyward by the explosion fall into soft deposits, deforming them as they land.

Spirit arrived at Home Plate in February 2006 and spent several months exploring it in detail before driving to "Low Ridge" to pass the martian winter. Spirit has now returned to Home Plate to continue exploration there. "We decided to go back to Home Plate, once the martian winter ended, because it is one of the most interesting places that we've found on Gusev Crater," Squyres said. "Last year we primarily explored the northern and eastern sides of it. This time we're hoping to get to the southern and western sides." Spirit's continued exploration of Home Plate will focus largely on testing the idea that water was involved in its formation process.

For images and more information about the rovers and their discoveries, *www.nasa.gov/vision/universe/solarsystem/mer_main.html* or *marsrovers.jpl.nasa.gov*.

The lower coarse-grained unit shows granular textures toward the bottom of the image and massive textures. Also shown in this false-color view is a feature interpreted to be a "bomb sag," which is 4 centimeters across. Credit: NASA/JPL-Caltech/USGS/Cornell.

Ice on Mars' South Pole is Deep and Wide

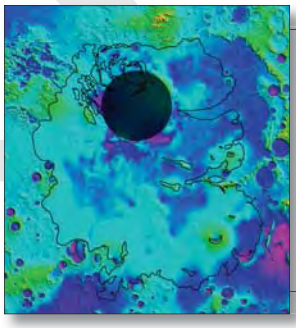
New measurements of Mars' south polar region indicate extensive frozen water. The polar region contains enough frozen water to cover the whole planet in a liquid layer approximately 36 feet deep. A joint NASA-Italian Space Agency instrument on the European Space Agency's Mars Express spacecraft provided these data.

This new estimate comes from mapping the thickness of the ice. The Mars Express orbiter's radar instrument has made more than 300 virtual slices through layered deposits covering the pole to map the ice. The radar sees through icy layers to the lower boundary, which is as deep as 2.3 miles below the surface. "The south polar layered deposits of Mars cover an area bigger than Texas. The amount of water they contain has been estimated before, but never with the level of confidence this radar makes possible," said Jeffrey Plaut of the Jet Propulsion Laboratory (JPL), co-principal investigator for the radar and lead author of a new report on these findings published in the March 15 online edition of the journal *Science*.

The instrument, named the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS), is also mapping the thickness of similar layered deposits at the north pole of Mars. Polar layered deposits hold most of the known water on modern Mars, although other areas of the planet appear to have been very wet at times in the past. Understanding the history and fate of water on Mars is a key to studying whether Mars has ever supported life, since all known life depends on liquid water.

The polar layered deposits extend beyond and beneath a polar cap of bright-white frozen carbon dioxide and water at Mars' south pole. Dust darkens many of the layers. However, the strength of the echo that the radar receives from the rocky surface underneath the layered deposits suggests the composition of the layered deposits is at least 90% frozen water. One area with an especially bright reflection from the base of the deposits puzzles researchers. It resembles what a thin layer of liquid water might look like to the radar instrument, but the conditions are so cold that the presence of melted water is deemed highly unlikely.

Detecting the shape of the ground surface beneath the ice deposits provides information about even deeper structures of Mars. "We didn't really know where the bottom of the deposit was," Plaut said. "Now we can see that the crust has not been depressed by the weight of the ice as it would be on the Earth. The crust and upper mantle of Mars are stiffer than the Earth's, probably because the interior of Mars is so much colder."



This map shows the topography of the south polar region of Mars, including topography buried by thick deposits of icy material. The map is a combination of surface elevation data acquired by the Mars Orbiter Laser Altimeter onboard the Mars Global Surveyor orbiter, and subsurface elevation data acquired by MARSIS onboard the Mars Express orbiter. The black line shows the boundary of the south polar layered deposits, an ice-rich geologic unit that was probed by MARSIS. Elevation values within the black outline show the topography at the boundary between the layered deposits and the underlying material, an interface known as the "bed" of the deposits. The elevation of the terrain is shown by colors, with purple and blue representing the lowest areas, and orange and red the highest. Credit: NASA/JPL/ASI/ESA/Univ. of Rome/MOLA Science Team/USGS.

Report Reveals Likely Causes of Mars Spacecraft Loss

After studying Mars four times as long as originally planned, NASA's Mars Global Surveyor orbiter appears to have succumbed to battery failure caused by a complex sequence of events involving the onboard computer memory and ground commands. The causes were released in April in a preliminary report by an internal review board. The board was formed to look more in-depth into why Mars Global Surveyor went silent in November 2006 and recommend any processes or procedures that could increase safety for other spacecraft.

Mars Global Surveyor last communicated with Earth on November 2, 2006. Within 11 hours, depleted batteries likely left the spacecraft unable to control its orientation. "The loss of the spacecraft was the result of a series of events linked to a computer error made five months before the likely battery failure," said board Chairperson Dolly Perkins, deputy director-technical of NASA Goddard Space Flight Center.

On November 2, after the spacecraft was ordered to perform a routine adjustment of its solar panels, the spacecraft reported a series of alarms, but indicated that it had stabilized. That was its final transmission. Subsequently, the spacecraft reoriented to an angle that exposed one of two batteries carried on the spacecraft to direct sunlight. This caused the battery to overheat and ultimately led to the depletion of both batteries. Incorrect antenna pointing prevented the orbiter from telling controllers its status, and its programmed safety response did not include making sure the spacecraft orientation was thermally safe.

The board also concluded that the Mars Global Surveyor team followed existing procedures, but that procedures were insufficient to catch the errors that occurred. The board is finalizing recommendations to apply to other missions, such as conducting more thorough reviews of all nonroutine changes to stored data before they are uploaded and to evaluate spacecraft contingency modes for risks of overheating. "We are making an end-to-end review of all our missions to be sure that we apply the lessons learned from Mars Global Surveyor to all our ongoing missions," said Fuk Li, Mars Exploration Program manager at the Jet Propulsion Laboratory.

Mars Global Surveyor, launched in 1996, operated longer at Mars than any other spacecraft in history, and for more than four times as long as the prime mission originally planned. The spacecraft returned detailed information that has overhauled understanding about Mars. Major findings include dramatic evidence that water still flows in short bursts down hillside gullies, and identification of deposits of water-related minerals leading to selection of a Mars rover landing site.

Information about the Mars Global Surveyor mission, including a list of some of the important discoveries by the mission, is available at *www.nasa.gov/mission_pages/mgs*.

Artist's concept of the Mars Global Surveyor spacecraft. Credit: NASA/JPL.

Cassini Spacecraft Images Seas On Saturn's Moon Titan

Instruments on the Cassini spacecraft have found evidence for seas, likely filled with liquid methane or ethane, in the high northern latitudes of Saturn's moon Titan. One such feature is larger than any of the Great Lakes of North America and is about the same size as several seas on Earth.

Cassini's radar instrument imaged several very dark features near Titan's north pole. Much larger than similar features seen before on Titan, the largest dark feature measures at least 39,000 square miles. Since the radar has caught only a portion of each of these features, only their minimum size is known. Titan is the second largest moon in the solar system and is about 50% larger than Earth's Moon. "We've long hypothesized about oceans on Titan and now with multiple instruments we have a first indication of seas that dwarf the lakes seen previously," said Jonathan Lunine, Cassini interdisciplinary scientist at the University of Arizona.

While there is no definitive proof yet that these seas contain liquid, their shape, their dark appearance in radar that indicates smoothness, and their other properties point to the presence of liquids. The liquids are probably a combination of methane and ethane, given the conditions on Titan and the abundance of methane and ethane gases and clouds in Titan's atmosphere. Cassini's visual and infrared mapping spectrometer also captured a view of the region, and the team is working to determine the composition of the material contained within these features to test the hypothesis that they are liquid-filled.

The imaging cameras, which provide a global view of Titan, have imaged a much larger, irregular dark feature. The northern end of their image corresponds to one of the radar-imaged seas. The dark area stretches for more than 620 miles in the image, down to 55°N latitude. If the entire dark area is liquid-filled, it would be only slightly smaller than Earth's Caspian Sea. The radar data show details at the northern end of the dark feature similar to those seen in earlier radar observations of much smaller liquid-filled lakes. However, to determine if the entire dark feature is a liquid-filled basin will require investigation through additional radar flyovers later in the mission. The presence of these seas reinforces the current thinking that Titan's surface must be resupplying methane to its atmosphere, the original motivation almost a quarter century ago for the theoretical speculation of a global ocean on Titan.

Cassini's instruments are peeling back the haze that shrouds Titan, showing high northern latitudes dotted with seas hundreds of miles across, and hundreds of smaller lakes that vary from several to tens of miles. More information about the Cassini mission is available at *www.nasa.gov/cassini*.

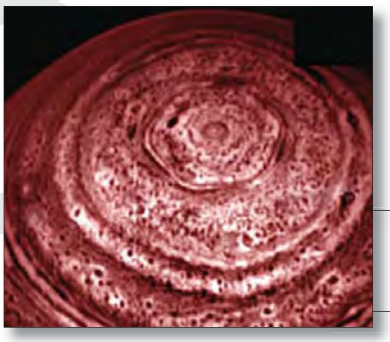
This side-by-side image shows a Cassini radar image of what is the largest body of liquid ever found on Titan's north pole, compared to Lake Superior. This close-up is part of a larger image and offers strong evidence for seas on Titan. These seas are most likely liquid methane and ethane. Credit: NASA/JPL/GSFC.

Cassini Images Bizarre Hexagon on Saturn

An odd, six-sided, honeycomb-shaped feature circling the entire north pole of Saturn has captured the interest of scientists with the Cassini mission. NASA's Voyager 1 and 2 spacecraft imaged the feature over two decades ago. The fact that it has appeared in Cassini images indicates that it is a long-lived feature. A second hexagon, significantly darker than the brighter historical feature, is also visible in the Cassini pictures. The spacecraft's visual and infrared mapping spectrometer is the first instrument to capture the entire hexagon feature in one image. "This is a very strange feature, lying in a precise geometric fashion with six nearly equally straight sides," said Kevin Baines, atmospheric expert and member of Cassini's visual and infrared mapping spectrometer team at the Jet Propulsion Laboratory. "We've never seen anything like this on any other planet. Indeed, Saturn's thick atmosphere where circularly-shaped waves and convective cells dominate is perhaps the last place you'd expect to see such a six-sided geometric figure, yet there it is."

The hexagon is similar to Earth's polar vortex, which has winds blowing in a circular pattern around the polar region. On Saturn, the vortex has a hexagonal rather than circular shape. The hexagon is nearly 25,000 kilometers (15,000 miles) across. Nearly four Earths could fit inside it. The new images taken in thermal-infrared light show the hexagon extends much deeper down into the atmosphere than previously expected, some 100 kilometers (60 miles)below the cloud tops. A system of clouds lies within the hexagon. The clouds appear to be whipping around the hexagon like cars on a racetrack.

"It's amazing to see such striking differences on opposite ends of Saturn's poles," said Bob Brown, team leader of the Cassini visual and infrared mapping spectrometer, University of Arizona, Tucson. "At the south pole we have what appears to be a hurricane with a giant eye, and at the north pole of Saturn we have this geometric feature, which is completely different." The Saturn north pole hexagon has not been visible to Cassini's visual cameras, because it's winter in that area, so the hexagon is under the cover of the long polar night, which lasts about 15 years. The infrared mapping spectrometer can image Saturn in both daytime and nighttime conditions and see deep inside. It imaged the feature with thermal wavelengths near 5 micrometers (seven times the wavelength visible to the human eye) during a 12-day period beginning on October 30, 2006. As winter wanes over the next two years, the feature may become visible to the visual cameras.



"Once we understand its dynamical nature, this long-lived, deep-seated polar hexagon may give us a clue to the true rotation rate of the deep atmosphere and perhaps the interior," added Baines. The hexagon images and movie, including the north polar auroras, are available at *www.nasa.gov/cassini*, *saturn.jpl.nasa.gov*, and *wwwvims.lpl.arizona.edu*.

This Cassini image, showing a honeycomb-shaped feature circling the entire north pole of Saturn, is one of the first clear images ever taken of the north polar region as seen from a unique polar perspective. Credit: NASA/JPL/University of Arizona.

Enceladus Geysers Mask the Length of Saturn's Day

In a David and Goliath story of saturnian proportions, the little moon Enceladus is weighing down giant Saturn's magnetic field so much that the field is rotating slower than the planet. This phenomenon makes it nearly impossible to measure the length of the Saturn day using techniques that work at the other giant planets.

"No one could have predicted that the little moon Enceladus would have such an influence on the radio technique that has been used for years to determine the length of the Saturn day," said Don Gurnett of the University of Iowa. Gurnett is the principal investigator on the radio and plasma wave science experiment onboard the Cassini spacecraft. The radio technique measures the rotation of the planet by taking its radio pulse rate — the rhythm of natural radio signals from the planet.

A new study of Cassini data reported in the online version of the journal *Science* determined that Saturn's magnetic field lines, invisible lines originating from the interior of a magnetized planet, are being forced to slip relative to the rotation of the planet by the weight of electrically charged particles originating from geysers spewing water vapor and ice from Enceladus. These results are based on joint observations by two Cassini instruments: the radio and plasma wave instrument and the magnetometer.

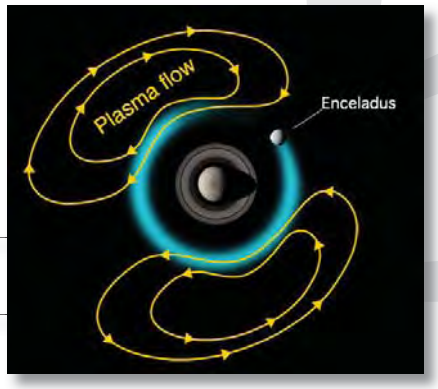
The neutral gas particles ejected from the geysers on Enceladus form a donut-like torus around Saturn. As these particles become electrically charged, they are captured by Saturn's magnetic field, forming a disk of ionized gas, or plasma, which surrounds the planet near the equator. The particles weigh down the magnetic field so much that the rate of rotation of the plasma disk slows down slightly. This slippage causes the radio period, controlled by the plasma disk rotation, to be longer than the planet's actual rotation period. Scientists conclude the period Cassini has been measuring from radio emission is not the length of the Saturn day, but rather the rotation period of the plasma disk. At present, because of Saturn's cloud motion, no technique is known that can accurately measure the planet's actual internal rotation.

Finding out the length of Saturn's day has been a challenge because the gaseous planet has no surface or fixed point to clock its rotation rate. Initially, the approach was to use periodic regular radio signals, as has been done for Jupiter, Uranus, and Neptune. However, Saturn's radio period has turned out to be troubling in two ways. It seems to be a pulsed signal rather than a rotating, lighthouse-like beam. Second, the period seems to be slowly changing over months to years. The day measured by Cassini is some six minutes longer than the day recorded by NASA's Voyager spacecraft in the early 1980s, a change of nearly 1%.

"We have linked the pulsing radio signal to a rotating magnetic signal. Once each rotation of Saturn's magnetic field, an asymmetry in the field triggers a burst of radio waves," said Dr. David Southwood, co-author, Imperial College London, and director of science at the European Space Agency. "We have then linked both signals to material that has come from Enceladus." Based on the new observations, scientists now think there are two possible reasons for the change in radio period. The first theory is that the geysers on Enceladus could be more active now than in Voyagers' time. The second is that there may be seasonal variations as Saturn orbits the sun once every 29 years.

"One would predict that when the geysers are very active, the particles load down the magnetic field and increase the slippage of the plasma disk, thereby increasing the radio emission period even more. If the geysers are less active, there would be less of a load on the magnetic field, and therefore less slippage of the plasma disk, and a shorter period," said Gurnett. "The direct link between radio, magnetic field, and deep planetary rotation has been taken for granted up to now. Saturn is showing we need to think further," said Michele Dougherty of Imperial College London, principal investigator on Cassini's magnetometer instrument.

The Saturn radio emissions detected by Cassini have been converted into an audio file available at *www.nasa.gov/cassini* and *saturn.jpl.nasa.gov*.



Geysers on Saturn's little moon Enceladus are throwing off Saturn's internal clock, making it hard to measure the length of the Saturn day. Credit: NASA/JPL.

A Hot Start Might Explain Geysers on Enceladus

A hot start billions of years ago might have set into motion the forces that power geysers on Saturn's moon Enceladus. "Deep inside Enceladus, our model indicates we've got an organic brew, a heat source and liquid water, all key ingredients for life," said Dennis Matson, Cassini project scientist at the Jet Propulsion Laboratory. "And while no one is claiming that we have found life by any means, we probably have evidence for a place that might be hospitable to life."

Since the Voyager spacecraft first returned images of the moon's snowy white surface, scientists have suspected Enceladus had to have something unusual happening within that shell. Cameras on the Cassini orbiter seemed to confirm that suspicion in 2005 when they spotted geysers on Enceladus ejecting water vapor and ice crystals from its south polar region. The challenge for researchers has been to figure out how this small ice ball could produce the levels of heat needed to fuel such eruptions.

A new model suggests the rapid decay of radioactive elements within Enceladus shortly after it formed may have jump-started the long-term heating of the moon's interior that continues today. The model provides support for another recent, related finding, which indicates that Enceladus' icy plumes contain molecules that require elevated temperatures to form. "Enceladus is a very small body, and it's made almost entirely of ice and rock. The puzzle is how the moon developed a warm core," said Julie Castillo, the lead scientist developing the new model at JPL. "The only way to achieve such high temperatures at Enceladus is through the very rapid decay of some radioactive species."

The hot start model suggests Enceladus began as a mixed-up ball of ice and rock that contained rapidly decaying radioactive isotopes of aluminum and iron. The decomposition of those isotopes — over a period of about 7 million years — would produce enormous amounts of heat. This would result in the consolidation of rocky material at the core surrounded by a shell of ice. According to the theory, the remaining, more slowly decaying radioactivity in the core could continue to warm and melt the moon's interior for billions of years, along with tidal forces from Saturn's gravitational tug.

From afar, Enceladus exhibits a bizarre mixture of softened craters and complex, fractured terrains. This large mosaic comprises 21 narrow-angle camera images that have been arranged to provide a full-disk view of the anti-Saturn hemisphere on Enceladus. Credit: NASA/JPL/Space Science Institute.

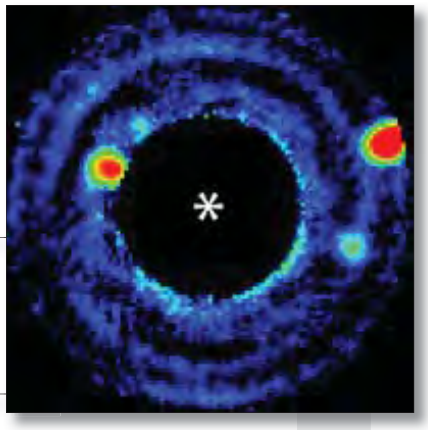
NASA Shows Future Space Telescopes Could Detect Earth Twin

For the first time ever, NASA researchers have successfully demonstrated in the laboratory that a space telescope rigged with special masks and mirrors could snap a photo of an Earth-like planet orbiting a nearby star. This accomplishment marks a dramatic step forward for missions like the proposed Terrestrial Planet Finder, designed to hunt for an Earth twin that might harbor life. Trying to image an exoplanet — a planet orbiting a star other than the Sun — is a daunting task, because its relatively dim glow is easily overpowered by the intense glare of its much bigger, brighter parent star. The challenge has been compared to looking for a firefly next to a searchlight.

Now, two researchers at the Jet Propulsion Laboratory have shown that a fairly simple coronagraph — an instrument used to "mask" a star's glare — paired with an adjustable mirror could enable a space telescope to image a distant planet 10 billion times fainter than its central star. "Our experiment demonstrates the suppression of glare extremely close to a star, clearing a field dark enough to allow us to see an Earth twin. This is at least a thousand times better than anything demonstrated previously," said John Trauger, lead author of a paper that appeared in the April 12 issue of *Nature*. This paper describes the system, called the High Contrast Imaging Testbed, and how the technique could be used with a telescope in space to see exoplanets. The lab experiment used a laser as a simulated star, with fainter copies of the star serving as "planets."

To date, scientists have used various techniques to detect more than 200 exoplanets. Most of these exoplanets are from 5 to 4000 times more massive than Earth, and are either too hot, too cold, or too much of a giant gas ball to be considered likely habitats for life. So far, no one has managed to capture an image of an exoplanetary system that resembles our own solar system. Scientists are eager to take a closer look at nearby systems, to hunt for and then characterize any Earth-like planets — those with the right size, orbit, and other traits considered friendly for life.

According to Wesley Traub of JPL, co-author of the paper and Terrestrial Planet Finder project scientist, "This result is important because it points the way to building a space telescope with the ability to detect and characterize Earth-like planets around nearby stars." More information on NASA's planet-finding missions, including Terrestrial Planet Finder, is available at *planetquest.jpl.nasa.gov*.



Three simulated planets — one as bright as Jupiter, one half as bright as Jupiter, and one as faint as Earth — stand out plainly in this image created from a sequence of 480 images captured by the High Contrast Imaging Testbed at JPL. A roll-subtraction technique, borrowed from space astronomy, was used to distinguish planets from background light. The asterisk marks the location of the system's simulated star. Credit: NASA/JPL-Caltech.

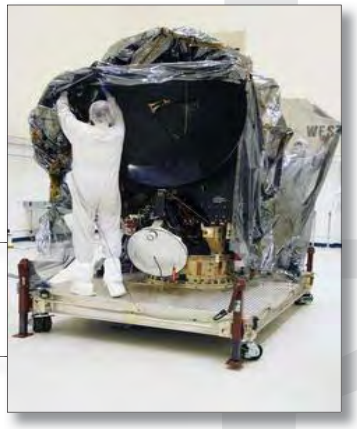
Dawn Arrives in Florida — A Little After Dawn

The Dawn spacecraft arrived at Astrotech Space Operations in Titusville, Florida, on April 10. Dawn, NASA's mission into the heart of the asteroid belt, is at the facility for final processing and launch operations. Dawn's launch period opens June 30.

"Dawn only has two more trips to make," said Dawn project manager Keyur Patel of the Jet Propulsion Laboratory. "One will be in mid-June when it makes the 15-mile journey from the processing facility to the launch pad. The second will be when Dawn rises to begin its eight-year, 3.2-billion-mile odyssey into the heart of the asteroid belt." The Dawn spacecraft will employ ion propulsion to explore two of the asteroid belt's most intriguing and dissimilar occupants: asteroid Vesta and the dwarf planet Ceres.

Now that Dawn has arrived at Astrotech near NASA's Kennedy Space Center, final prelaunch processing has begun. Technicians are at work installing the spacecraft's batteries, checking out the control thrusters, and testing the spacecraft's instruments. In late April, Dawn's large solar arrays were attached and then deployed for testing. In early May, a compatibility test was performed with the Deep Space Network used for tracking and communications. Dawn was then loaded with fuel to be used for spacecraft control during the mission. Finally, the spacecraft will undergo spin-balance testing. Dawn will then be mated to the upper stage booster and installed into a spacecraft transportation canister for the trip to Cape Canaveral Air Force Station. This is currently scheduled for June 19, when it will be mated to the Delta II rocket at Pad 17-B.

Additional information about Dawn is available at *dawn.jpl.nasa.gov*.



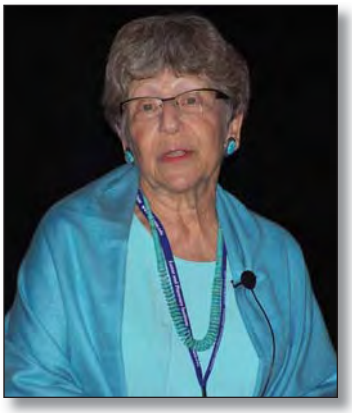
In clean room C of Astrotech's Payload Processing Facility, a worker wearing a "bunny suit," or clean-room attire, begins removing the protective cover surrounding the Dawn spacecraft. Credit: NASA/George Shelton.

38th Lunar and Planetary Science Conference March 12–16, 2007, League City, Texas

The 38th Lunar and Planetary Science Conference (LPSC), held in March at the South Shore Harbour Resort and Conference Center in League City, Texas, was a resounding success. Over 1500 planetary scientists (nearly 400 of them students) from all over the world gathered this year at the annual meeting, which once again lived up to its well-deserved reputation of the premiere gathering of planetary scientists in the world.

The resurgence of excitement and interest in lunar exploration, the wealth of information being returned daily from the current Mars missions, and the stunning images of the saturnian system all contributed to the variety of new research unveiled at the conference.

"LPSC is clearly the 'must-attend' meeting of the year," said Dr. Walter Kiefer, staff scientist at the Lunar and Planetary Institute. "Not only is it the place to get caught up on all the research that's been done over the last year, but it provides the best venue at which to have your work presented to the widest and most interested audience."


Margaret Kivelson

Monday's program featured sessions on Mars polar and glacial processes, calcium-aluminum-rich inclusions, planetary differentiation, impact cratering, Titan, Mars volcanism, Mars polar layered deposits, and early solar system isotopes. Monday afternoon's plenary session highlighted the 2006 Dwornik student award winners, followed by the Masursky Lecture by Dr. Margaret Kivelson, "Magnetized Plasmas as Probes of the Atmospheres, Surfaces, and Interiors of the Moons of the Outer Planets." Kivelson is a distinguished senior scientist, a member of the National Academy of Sciences, and was the 2005 recipient of the American Geophysical Union's John Adam Fleming Medal, which recognizes original research and technical leadership in geomagnetism, atmospheric electricity, aeronomy, space physics, and related sciences. Kivelson has had a remarkable career in the fields of solar-terrestrial physics and heliospheric and planetary science, with particular emphasis on planetary magnetism. Following the afternoon sessions, representatives from NASA Headquarters presented a briefing to the community about the status of various NASA programs, missions, and lunar exploration goals.

Other sessions throughout the week featured such diverse topics as solar system formation; achondrites, chondrites, and martian meteorites; asteroid observations; presolar and solar grains; studies of the lunar interior and differentiation processes on the Moon; martian magnetics and atmosphere, sediments and geochemistry, surface processes and evolution, and cratering; the latest results from the Stardust mission; astrobiology; and icy satellites.

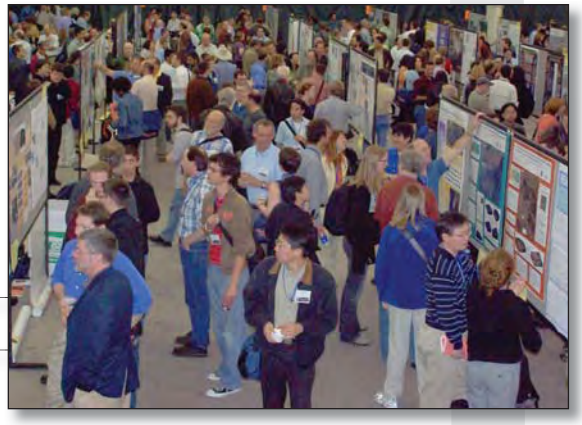

NASA Headquarters briefing.

The conference also featured special sessions on the latest results from the Mars Reconnaissance Orbiter and SMART-1, as well as a special session devoted to volcanism and tectonism on saturnian satellites. With 501 oral presentations and more than 800 poster presentations, this year's LPSC clearly offered something for everyone.

Open house displays of education and public outreach activities.

Mars Reconnaissance Orbiter press conference on Monday, March 12.

Open house and registration on Sunday, March 11.



Tuesday night poster session.

Participants from Non-U.S. Countries

Algeria:	1	Ireland:	3
Australia:	5	Italy:	11
Austria:	2	Japan:	83
Belgium:	3	Mexico:	1
Canada:	34	Netherlands:	5
Croatia:	1	Norway:	2
Denmark:	1	Portugal:	1
Estonia:	2	Russia:	7
Finland:	5	South Africa:	2
France:	43	Spain:	4
Germany:	61	Switzerland:	10
Hungary:	8	United Kingdom:	49
India:	2		

International Collaboration on Lunar Science: Results of the 2nd Annual Meeting of the Lunar Reconnaissance Orbiter Project Science Working Group
November 28–30, 2006, University of Hawai'i

— Reported by Gordon Chin (NASA Goddard), John Keller (NASA Goddard), and Cherilynn Morrow (SETI Institute)

In 2007–2008, there will be an unprecedented demonstration of international spacefaring capacity as four countries (China, Japan, India, and the U.S.) launch lunar orbiters, all of them as a prelude to larger national plans for lunar exploration. Recognizing the extraordinary potential for international coordination and collaboration, the Project Science Working Group (PSWG) of the U.S. mission, the Lunar Reconnaissance Orbiter (LRO), invited representatives of all upcoming lunar missions to their second annual meeting in November 2006. The workshop format provided an unprecedented opportunity for detailed working discussions among scientists, instrument P.I.s, engineers, and data managers about specific opportunities for international cooperation. This article provides background on LRO and the PSWG, and then summarizes meeting outcomes.

NASA's Lunar Reconnaissance Orbiter and the Project Science Working Group

Lunar Reconnaissance Orbiter

The Lunar Reconnaissance Orbiter (LRO) is scheduled to launch in late October 2008 as part of a $550 M (total mission cost) project to explore the lunar surface in exceptional detail. LRO will be placed in a low (50 km), circular, polar orbit that will provide global coverage of the Moon with a focus on the poles. In its first year of operation, LRO's suite of instruments will produce 300 Terabytes of data — more than all other U.S. planetary missions combined, including the Mars Reconnaissance Orbiter. Among several other compelling data products, LRO will obtain thousands of high-resolution (0.5-meter per pixel) images of the Moon, precision lidar topographic maps, infrared thermal maps, neutron spectroscopy data that can localize enhanced hydrogen concentrations in permanently shadowed regions, ultraviolet images that can peer into the dark interiors of shadowed craters, measurement of energy deposited in tissue equivalent plastic from the radiation environment, and radar measurements in S- and X-band (see *Chin et al.*, 2007). The LRO mission will also include a secondary payload called LCROSS (Lunar Crater Observation and Sensing Satellite), a separate mission, that will impact into the Moon's south polar region so that the resulting plume can be analyzed.

The LRO Project Science Working Group (PSWG) works to optimize the scientific return of the LRO mission. The heart of the PSWG is a team of seven experienced instrument P.I.s who are distributed at six distinguished institutions across the U.S. and one in Russia. The PSWG is led by Project Scientist Gordon Chin (NASA GSFC), and includes Deputy Project Scientist John Keller, LRO Data Manager Stan Scott, and Instrument Manager Arlen Bartels. LRO project engineers and education leads are also affiliated with the PSWG.

Participants and Objectives of the Meeting

The second annual meeting of the LRO PSWG took place on November 28–30, 2006, two weeks after the successful completion of the LRO Critical Design Review, which gave the official go-ahead for spacecraft construction. The meeting was convened at the East-West Center on the University of Hawai'i campus, a location that made the meeting more accessible to Asian colleagues. Participants included approximately 100 scientists, educators, engineers, and students representing the India Space Research Organization, Japanese Aerospace Exploration Agency, European Space Agency, Russian Space Agency, Italian Space Agency, NASA field centers, NASA Headquarters, Jet Propulsion Laboratory, U.S. Geological Survey, several nongovernmental organizations, and aerospace companies.

The objectives of this PSWG meeting were to determine the first steps toward (1) employing a standard lunar coordinate system on all missions, (2) establishing a standard set of calibration targets for instrument

cross calibration and comparison between missions, (3) formulating opportunities for scientific collaboration between missions, (4) allowing international access of data from all lunar missions in a standard format, and (5) coordinating a program of international education and public outreach (EPO) based on lunar exploration. Co-author Morrow designed the format of the PSWG meeting, which included breakout groups on each of these topics that were informed by preparatory briefings and preliminary white papers. Each of the five breakout groups was charged with identifying opportunities, obstacles, and options for progress. Preliminary results were reported to plenary for feedback and then finalized by the group facilitators and recorders.

The key results of the PSWG meeting are summarized below according to each breakout topic. More comprehensive results of the meeting, complete with presentations, are posted on the LRO website home page at *lunar.gsfc.nasa.gov*, with a link directly to *lunar.gsfc.nasa.gov/library-pswg.html* for PDF downloads.

A Common Lunar Coordinate System for All Missions
Facilitator: Maria Zuber; Recorders: Brent Archinal and Lisa Gaddis

Although data in different systems are only a transformation away, the opportunity to avoid confusion and eliminate inaccuracies can be taken advantage of through a prior agreement to use the same system in registering measurements by all lunar missions. A common coordinate system will also allow easier data identification, access, and comparison. The primary obstacle is that two different coordinate systems are currently in use for the Moon: (1) the mean Earth (ME)/polar axis and (2) the principal axis (PA).

For its data presentations, the LRO Project has adopted the ME system with longitude from 0° to 360° in the east direction (see *Standish et al.*, 1995). The PA system might be used (as the LRO Laser Altimeter team intends to do) as an internal system for observation planning. The consensus recommendation of the breakout committee is to advocate the adoption of the ME system by all lunar missions for data registration, following IAU/IAG standards (*Seidelmann et al.*, 2007). This would help to allow the improved geodetic control system expected to result from the LRO mission to be applied retroactively to data from all international lunar missions.

This breakout group also recommended that work continue on issues related to lunar constants and standards, both to gain widespread agreement that the ME system should be used, and to address other issues as they arise. This should be done initially through the LRO project, until a Lunar Geodesy and Cartography Working Group (using the NASA Mars Geodesy and Cartography Working Group as a model) can take over such an effort.

Lunar Calibration Targets for Cross-Calibration Among Missions
Facilitator: Carle Pieters; Recorder: David Smith

The adoption of standard lunar calibration sites offers the opportunity to compare data obtained from instruments on different spacecraft and previous missions. An initial set of five proposed target sites initiated lively discussions: the Apollo 16 landing site, Lichtenberg Crater, Hadley Rille, the South Pole-Aitken Basin thorium anomaly areas, and Tycho Crater. These sites represent different terrain types and science opportunities. In addition, several lunar areas are of common interest for "ground truth" (Apollo and Luna landing sites) or science (SMART-1, LCROSS impact site).

There are a number of subtle issues that complicate the use of the suggested sites for calibration purposes. For example, sites that offer interesting science opportunities are generally highly complex and not accessible for all types of instruments. Observations at differing scales of a site may make accurate comparisons difficult. Not all sites will be relevant for all instruments, and some measurements might have sensitivity to different depths. Even for relatively similar imaging instruments, comparisons are challenged by different observational conditions such as lighting, observing angle, and orbital geometry.

Three additional calibration sites (high-latitude region, polar area, and homogenous mare region) were recommended that will increase the applicability and adoption of the cross calibration targets by all missions. These recommendations were captured in the revised version of *Pieters et al.* (2007), which now includes the three additional suggested sites as well as detailed comments about instrument diversity that arose from the session discussions.

Opportunities for Cooperative Activities Among Missions
Facilitator: Alan Stern; Recorder: John Keller

There are numerous opportunities for scientific collaboration among all lunar missions as well as for coordination with ground and space facilities. The most pressing examples include coordinating observations of the LCROSS impact site, conducting bistatic radar experiments between LRO and the Indian mission (Chandrayaan-1) using their similar radar systems, and collaborating on early observations of the fragile lunar exosphere before perturbations by orbiting satellite effluents and impacts contaminate the baseline measurements.

Obstacles that complicate coordination of observational efforts include (1) concerns for RF interference and safety from powerful groundbased radar systems such as at Arecibo that are used to observe the Moon; (2) inadequate time and opportunity to examine and prioritize all the potential opportunities; (3) the need for approval at many levels within the respective agencies and even at higher levels of governments; and (4) the need for each mission to concentrate on predefined requirements that may or not be compatible with other missions.

To help overcome these obstacles, the group advised a concentration on coordination between missions that have overlapping objectives such as selecting a landing site, using a particular calibration target, or making similar scientific observations. They also recommended coordination of missions work to maximize the coverage of lunar imagery using similar phase angles and lighting conditions. Finally, the session members advocated the formation of a working group composed of instrument P.I.s, project scientists, agency leadership, and members of the lunar science community to prioritize potential cooperative efforts.

International Access to Data from All Lunar Missions
Facilitator: Susan Slavney; Recorder: Edward Guinness

The opportunity to have international access to all lunar data will facilitate the use of standard calibration sites, help to refine lunar gravity models, enable informal team-to-team exchanges for data comparison and analysis, permit the general public to view lunar images, and support agency agreements for program planning.

Obstacles that hinder international access to data include P.I. rights to early research and publication, the requirement that informal scientist-to-scientist agreements obtain prior agency approval, potential International Traffic in Arms Regulation (ITAR) restrictions for U.S. data, and a lack of common standards for data archiving and formatting.

Options to overcome these obstacles include prior definition of methods for making science team-to-science team agreements, and incremental data releases rather than single end-of-mission data deposits. This breakout group also recognized that the Interplanetary Data Alliance (IPDA) has formulated a data access protocol that allows users to query both the Planetary Data System (PDS) and ESA's Planetary Science Archive catalogs. Essential considerations include development of (1) web-based access tools with common features for searching and downloading data; (2) a minimum common set of meta-data to allow searching for data across missions; (3) a means of quality control using peer review of data by the archiving agency; and (4) peer review of results by a science journal.

Coordination of International Education and Public Outreach (EPO) Opportunities
Facilitator: Cherilynn Morrow; Recorder: Stephanie Stockman

All cultures have powerful relationships to the Moon, whether in terms of a traditional naked-eye observing, modern exploration, or both. Space agencies around the world are becoming increasingly attentive to

education and public outreach (EPO) associated with their missions. The upcoming international suite of lunar missions presents an extraordinary opportunity to engage a broader worldwide audience in the exciting science and technology of lunar exploration through international cooperation in associated EPO efforts.

For the past 10 years, NASA space science missions have all included well-supported EPO plans. LRO's emerging program is led by Stephanie Stockman at NASA GSFC. Cherilynn Morrow of the SETI Institute has been working on developing an international EPO coordination role that would amplify the EPO efforts of LRO and other missions. The vision is to allow all missions to leverage from each other's programs and thereby reach a wider global audience for the EPO materials and events they produce. As these missions unfold there is an opportunity to develop an international program that will continue to pay dividends well past the currently planned missions by putting in place the infrastructure to support the follow-on endeavors.

Obstacles cited by this breakout group were (1) space agencies are somewhat constrained internally to serve their national audiences with no exchange of funding internationally; (2) some EPO products are copyrighted or proprietary, such as the commercial video cameras on the Japanese mission (SELENE); (3) there is a language barrier that must be overcome to effectively leverage the world's collective lunar exploration efforts; and (4) significant portions of the U.S. audience consider lunar exploration passé or irrelevant to their lives.

This breakout group raised a number of specific options to address these obstacles and realize opportunities. These may be binned into four categories: (1) emphasis on existing points of contact between missions, such as Russian participation on LRO and U.S. participation on the Indian mission (Chandrayaan-1); (2) working through accepted international professional societies and working groups such as COSPAR, AGU, EGU, the International Space University, the International Planetarium Society (meeting in Chicago in 2008), the International Lunar Exploration Working Group (ILEWG), and the UN program for basic space science in developing countries; (3) leveraging international outreach and translation capacity with International "Years" or "Decades" such as the International Heliophysical Year and the emerging International Lunar Decade proposed by the Planetary Society; and (4) enhancing lunar content in EPO programs that are already global, such as GLOBE (linking Earth to Moon). In all cases, it is important to provide compelling answers to the question "Why the Moon?"

Representatives of existing EPO programs associated with prior lunar or Mars missions also raised the possibility of formally extending their efforts to a broader worldwide audience using the new lunar data that will be obtained. ESA's SMART-1 mission could extend their Earth View and Adopt-a-Crater programs. NASA's Mars Student Imaging program and Museum Visualization Alliance could extend to international participation with lunar content.

Summary

The initial steps have been taken by the PSWG to open discussion by a broad community of participants to recognize by putting forward international opportunities, obstacles, and options on a range of practical goals that can be realized by all missions. The key recommendation is to "keep talking to all mission teams" in future meetings and to build on the momentum gathered by the second annual LRO PSWG.

Acknowledgments. Kristina Safdie, with help from Tricia Gregory, organized the second annual PSWG meeting extraordinarily well by solving the countless problems required to ensure smooth running at the East-West Center.

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Spotlight on Education

"Spotlight on Education" highlights events and programs that provide opportunities for space 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 South Central Organization of Researchers and Educators at score@lpi.usra.edu.

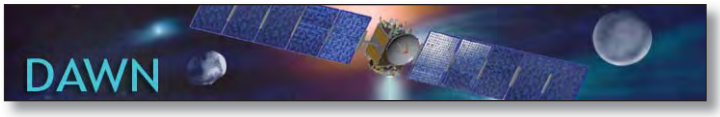
Small E/PO Grants for Scientists Available from the Astronomical Society of the Pacific

In an effort to encourage active researchers to engage in public outreach, K–14 formal education, or informal education programs or activities to improve the understanding, appreciation, and enjoyment of astronomy, the Astronomical Society of the Pacific has instituted a new small grants program. The application, funding, and reporting processes have been streamlined to minimize the time investment associated with obtaining and fulfilling the obligations of these grants. Proposals for up to $2500.00 are being accepted from institutions or individuals. Any active researcher in astronomy, astrophysics, or space science residing in the U.S., Canada, or Mexico is eligible. The application deadline is June 15, 2007. For complete information, go to *www.astrosociety.org/education/grants/grants.html*.

E/PO and a Changing World: Creating Linkages and Expanding Partnerships

The Astronomical Society of the Pacific's annual E/PO Conference and 119th Annual Meeting will take place on September 5–7, 2007, in Chicago. The national conference will focus on building and supporting a vibrant and connected community of individuals and groups engaged in educational and public outreach (E/PO) in the disciplines of astronomy, astrobiology, space, and Earth science. E/PO professionals in astronomy and space science; scientists involved in E/PO; formal, informal, and volunteer educators; science coordinators; and public information professionals are encouraged to attend. Abstracts are due by May 14, 2007. Meeting information can be found at *www.astrosociety.org/events/meeting.html*.

Dawn Mission Education Opportunities



The Dawn mission, set to launch on June 30, 2007, offers a great opportunity to engage teachers — and students — in NASA science and exploration. The Dawn Feature Video, narrated by Leonard Nemoy, provides audiences with a glimpse into the planning, instrumentation, and technological challenges of the project. Several classroom modules for middle- and high-school students, developed to complement the mission science and engineering, are available on the website. These multiweek investigations explore the history and discovery of asteroids, the structure and properties of matter and ion propulsion, and the characteristics of meteorites. A Dawn Launch Educator Conference is planned for June. Scientists are encouraged to use these materials to introduce the mission to educators and the public. Dawn classroom materials can be accessed at *dawn.jpl.nasa.gov/DawnClassrooms/index.asp*.

2007 Exploring Space Lectures of The National Air and Space Museum

Journey Through the Outer Solar System features three presentations about current NASA missions in the distant regions of the solar system. Each lecture, scheduled for 8:00 p.m. Eastern, is available online following the live event. More information can be found at *www.nasm.si.edu/events/lectures/esls/esls.cfm*.

Archived: Exploring the Surface of Titan with Cassini-Huygens
Elizabeth Turtle, Johns Hopkins University Applied Physics Lab

May 8: Expedition to the Ringed Planet: Cassini Explores Saturn, Its Rings, and the Fountains of Enceladus
Carolyn Porco, Cassini Imaging Team Leader

June 14: New Horizons: Exploring the Solar System's Frontier
Alan Stern, Principle Investigator, New Horizons

Spanish-Language Space and Planetary Science Resources

Are you serving a Spanish-speaking audience? A variety of Spanish-language educational resources make space and planetary science more accessible.

Auroras! Luces Misteriosas en el Cielo
stargazers.gsfc.nasa.gov/pdf/products/books/aurora_sp.pdf
This coloring book for grades K–4 explores auroras and what makes them happen.

Ciencia@NASA
ciencia.nasa.gov
Headline news at NASA. Additional NASA Spanish-language sites can be found at *www.nasa.gov/about/highlights/En_Espanol.html*.

Cindi En El Espacio
cindispace.utdallas.edu/education/Cindi_comic_spanish_cc4.pdf
Spanish version of the *Cindi in Space* comic book — the story of the android spacegirl Cindi and her two dogs who explain the purpose of the CINDI instrument as part of the C/NOFS mission and the science involved.

Enciclopedia de Agujeros Negros
blackholes.radiouniverso.org
The black hole website from the University of Texas.

GLOBE Project
www.globe.gov/fsl/welcome/welcomeobject.pl?&lang=es&nav=1
Elementary- through high-school students make local environmental measurements and send their data, via the Internet, to the GLOBE Student Data Archive.

La Exploración de la Magnetosfera Terrestre
www-istp.gsfc.nasa.gov/Education/MIntro.html
Detailed content enables educators to explore Earth's magnetosphere. Activities and a plethora of additional resources support classroom learning.

NASA Kids Science News Network in Spanish
ksnnsp.larc.nasa.gov/intro.html
These one-minute newsbreaks for elementary students feature children teaching mathematics, science, technology, and facts about NASA. Activities, a glossary, quizzes, and resources for each topic are available.

Nuestra Propia Estrella: El Sol
stargazers.gsfc.nasa.gov/pdf/products/books/our_very_own_star_sp.pdf
An informative coloring book about the Sun, our very own star, for grades K–4. An animated version can be found at *stargazers.gsfc.nasa.gov/pdf/products/books/Sun_booklet_Spanish.htm*.

Space Place en Español
spaceplace.nasa.gov/sp/kids
Children ages 5–10 will enjoy this interactive exploration of Earth, the solar system, and beyond. Games, animations, puzzles, activities, and classroom lessons are available.

Spanish Language Astronomy Materials Education Center
www.astronomyinspanish.org
The National Optical Astronomy Observatory offers a searchable database of Spanish-language educational books, media, and periodicals, broken down by grade level.

Spitzer — El Telescopio Espacial
www.spitzer.caltech.edu/espanol
Images, news, and information about the Spitzer mission.

Tormentas Solares (*www-istp.gsfc.nasa.gov/istp/outreach/cmeposter/spindex.html*)
"Storms from the Sun" shares content for high-school students and educators about our dynamic star and how it influences Earth. Missions and current solar activity are highlighted.

Universo! (*radiouniverso.org*)
From the University of Texas' McDonald Observatory, this website contains the daily Universo radio show, the guide to the solar system, K–12 activities, and more.

Windows on the Universe (*www.windows.ucar.edu/spanish.html*)
This rich website shares information about Earth, our solar system, and universe in an accessible and engaging manner on multiple learning levels. Educator resources include lesson plans, supporting content.

Interested in becoming more involved in space science education and public outreach? NASA's Space Science Education and Public Outreach Support Network encompasses a nationwide network of Broker/Facilitators and Education Forums that are prepared to assist space science investigators in developing high-quality, high-impact E/PO programs. For more information about the network, or to contact the Broker/Facilitator in your region, please visit science.hq.nasa.gov/research/ecosystem.htm.

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.

Dr. Paul Schenk,
Scientific Editor (*schenk@lpi.usra.edu*)
Renée Dotson,
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The Lunar and Planetary Information Bulletin is published by the Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.

Editor: Paul Schenk
Production Editor: Renée Dotson
Graphic Design: Leanne Woolley

The Bulletin welcomes articles dealing with issues related to planetary science and exploration. The copy deadline for the next issue is July 13, 2007. 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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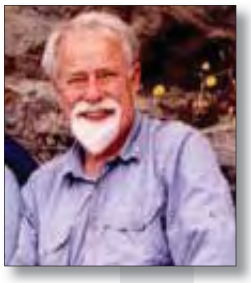
ISSN 1534-6587

In Memoriam

Robert Hutchison



Robert Hutchison, prominent member of the Meteoritical Society, Fellow since 1976, Councilor 1973–1974, and long term curator of meteorites at the Natural History Museum in London, died suddenly on January 26, 2007. He was 68. Hutchison was born in Glasgow and attended the University of Glasgow for his B.Sc. and Ph.D. degrees. After short periods at the Universities of Keele and Leeds, and with the Geological Survey in Nigeria, he held his position at the museum from 1969 until his retirement in 1997. Even after retirement he continued research, publishing his second book *Meteorites: A Petrologic, Chemical and Isotopic Synthesis* in 2004; his first, *The Search for Our Beginning, was* being published in 1983. For most of his tenure at the museum, Hutchison was also the main author of the *Catalogue of Meteorites*, a standard reference for all meteorite researchers. Hutchison played an important part in the discovery that SNC meteorites have young crystallization ages, a pivotal observation in the realization that they are from Mars, but he is best known for his work on chondrules. Throughout his life Hutchison advocated a planetary origin for chondrules, a view widely rejected at the time, but now gradually gaining popularity. His wife of 45 years, Marie, also a Scot, and a very popular participant of Meteoritical Society meetings, survives him.

For more about the life of Robert Hutchison, read the articles published in *The Independent* (*news.independent.co.uk/people/obituaries/article2412728.ece*) and *The Scotsman* (*news.scotsman.com/obituaries.cfm?id=529992007*).

Eugene Jarosewich

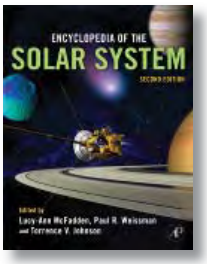
Eugene Jarosewich passed away at his home on April 30, 2007. Born in 1926, Jarosewich joined the Smithsonian's Department of Mineral Sciences in 1964, where he soon became Head Chemist. He retired in 1998, but remained active as Chemist Emeritus. He was an expert in the instrumental analysis of rocks and minerals, and in pursuing these interests he developed the department's analytical laboratories into a world-class facility for the analysis of geological materials. Jarosewich was known in the meteoritics community for having accomplished superb wet chemical analyses of meteorites, and for developing the only meteorite whole-rock standard through his work on specimens of Pueblo de Allende (1969). Working with specimens from the National Mineral Collection, in the 1970s he and his co-workers developed a set of standards for electron microprobe analysis, which to this day are distributed and used worldwide. These accomplishments are lasting legacies of a distinguished career. Jarosewich was particularly well known to members of the Meteoritical Society and The Microbeam Analysis Society, but he cooperated broadly both within the Smithsonian Institution and the international scientific community.

Walter M. "Wally" Schirra

Wally Schirra, the only astronaut to fly in each of the Mercury, Gemini, and Apollo programs, died on May 3, 2007, at the age of 84. Born March 12, 1923, in Hackensack, New Jersey, Schirra's NASA career began with his selection as one of the original seven Mercury astronauts in 1959 and spans the period from America's first tentative steps into space to the missions to the Moon.

Schirra flew on the fifth Mercury flight in 1962, orbiting the Earth six times. Schirra also commanded Apollo 7, the first manned Apollo flight. During that 11-day flight in Earth orbit in 1968, he and fellow crewmembers Walt Cunningham and Donn Eisele tested the Apollo systems and proved it was ready to take astronauts to the Moon. In what was a precursor of things to come, Apollo 7 transmitted the first television feed live into commercial networks from space during its 260-hour flight. "With the passing of Wally Schirra, we at NASA note with sorrow the loss of yet another of the pioneers of human spaceflight," NASA Administrator Michael Griffin said. "As a Mercury astronaut, Wally was of a member of the first group of astronauts to be selected, often referred to as the Original Seven." Fellow Mercury astronaut Scott Carpenter called Schirra a "dear friend, cherished comrade and a brother." "Despite our good natured competition for flights into space," said Carpenter, "Wally strove to bring a smile to everyone he met and it's with a smile that I will forever fondly remember him."

Books

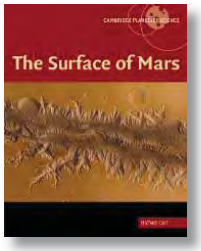


Encyclopedia of the Solar System, Second Edition. Edited by Lucy-Ann McFadden, Paul Weismann, and Torrence Johnson. Academic Press, 2006. 992 pp., Hardcover, $99.95. *books.elsevier.com*

Long before Galileo published his discoveries about Jupiter, lunar craters, and the Milky Way in the *Starry Messenger* in 1610, people were fascinated with the planets and stars around them. That interest continues today, and scientists are making new discoveries at an astounding rate. Ancient lakebeds on Mars, robotic spacecraft missions, and new definitions of planets now dominate the news. How can you take it all in? Start with the new *Encyclopedia of the Solar System, Second Edition*. This self-contained reference follows the trail blazed by the bestselling first edition. It provides a framework for understanding the origin and evolution of the solar system, historical discoveries, and details about planetary bodies and how they interact — and has jumped light years ahead in terms of new information and visual impact. Offering more than 50% new material, this volume includes the latest explorations and observations and hundreds of new color digital images and illustrations. It stands alone as the definitive work in this field, and will serve as a modern messenger of scientific discovery and provide a look into the future of our solar system.

New Views of the Moon. Edited by Bradley L. Jolliff, Mark A. Wieczorek, Charles K. Shearer, and Clive R. Neal. Mineralogical Society of America, 2006. 772 pp., Paperback, $45.00. *www.minsocam.org*

This book assesses the current state of knowledge of lunar geoscience, given the datasets provided by missions of the 1990s, and lists remaining key questions as well as new ones for future exploration to address. It documents how a planet or moon other than the world on which we live can be studied and understood in light of integrated suites of specific kinds of information. The Moon is the only body other than Earth for which we have material samples of known geologic context for study. This book seeks to show how the different kinds of information gained about the Moon relate to each other and also to learn from this experience, thus allowing more efficient planning for the exploration of other worlds.



The Surface of Mars. Michael Carr. Cambridge University Press, 2006. 322 pp., Hardcover, $135.00. *www.cup.org*

Our knowledge of Mars has grown enormously over the last decade as a result of the Mars Global Surveyor, Mars Odyssey, Mars Express, and Mars Exploration Rover missions. This book is a systematic summary of what we have learned about the geological evolution of Mars as a result of these missions. It describes the diverse martian surface features and summarizes current ideas as to how, when, and under what conditions they formed, and explores how Earth and Mars differ and why the two planets evolved so differently. The author also discusses possible implications of the geologic history for the origin and survival of indigenous martian life. Up to date and heavily illustrated, this book will be a principal reference for researchers and graduate students in planetary science. The comprehensive list of references will also assist readers in pursuing further information on the subject.

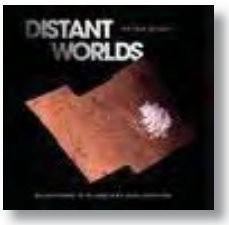
Pluto and Beyond: A Story of Discovery, Adversity, and Ongoing Exploration. Anne Minard. Northland Publishing, 2007. 192 pp., Paperback, $16.95. *www.northlandbooks.com*

This book peers under the dome of the Lowell Observatory, one of the few remaining privately owned observatories, home to the discoverer of Pluto more than 75 years ago and the future Discovery Channel Telescope. Fascinating stories illuminate the extraordinary personalities of the astronomers behind the startlingly disproportionate contributions in the field of astronomy that for more than 100 years have been hidden in the mix of groundbreaking science, some of

which opened the doors to phenomenal work done by the Hubble Space Telescope. *Pluto and Beyond* frames the larger questions facing astronomers today as they ponder the idea of what constitutes a planet and peer farther into the Kuiper belt to investigate objects orbiting there and beyond.

Protostars and Planets V. Edited by Bo Reipurth, David Jewitt, and Klaus Keil. University of Arizona Press, 2007. 976 pp., Hardcover, $90.00. *www.uapress.arizona.edu*

Increasing discoveries of new planets beyond our solar system are invigorating the quest for new knowledge and understanding of the birth of stars and planets. This new volume in the Space Science Series, with 249 contributing authors, builds on the latest results from recent advances in ground- and space-based astronomy and in numerical computing techniques to offer the most detailed and up-to-date picture of star and planet formation, including the formation of our own solar system. This book emphasizes the cross-disciplinary aspects of the field, with a particular focus on the early evolution of our solar system. *Protostars and Planets V* is the new foundation for further advancement in the fields of stellar and planetary formation, making it an indispensable resource for researchers and students in astronomy, planetary science, and the study of meteorites.



Distant Worlds: Milestones in Planetary Exploration. Peter Bond. Springer, 2007. 326 pp., Hardcover, $32.50. *www.springer.com*

In this overview of where planetary exploration stands today, the author describes the achievements of the astronomers, space scientists, and engineers who have made the exploration of our solar system possible. This compelling account of the Space Age includes dramatic accounts of the daring, resourcefulness, and ferocious competitive zeal of renowned as well as almost-forgotten space pioneers; clear explanations of the precursors to modern astronomy, including how ancient natural philosophers and observers first took the measure of the heavens; more than 100 informative photographs, maps, simulated scenarios, and technical illustrations, many in full color; appendices on the physical properties of our solar system; as well as a comprehensive list of 50 years of solar system missions. The book is organized into 12 chapters focusing on the objects of our exploration: individual planets, our Moon, and asteroids and comets. Bond's text shows how the great human enterprise of space exploration may on occasion have faltered or wandered off the path, but taken as a whole amounts to one of the great triumphs of human civilization.

Posters

Geologic Effects of Impact Cratering. Lunar and Planetary Laboratory Space Imagery Center, 2007. 23-inch by 29-inch poster, $5.50. *www.lpl.arizona.edu/SIC/poster2.html*

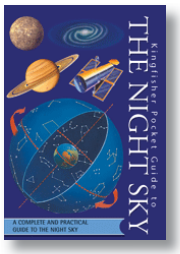
This colorful poster shows geological effects of impact cratering, such as crater formation, shock quartz, transition crater diameter, breccia, and shattercones. This is a new companion poster to the *Environmental Effects of Impact Cratering* poster of 2002.

Online Resources

Cosmic Journey: A History of Scientific Cosmology.
www.aip.org/history/cosmology/

This new website tells with unprecedented depth, accuracy, and excitement how scientists have explored the structure of the universe. *Cosmic Journey: A History of Scientific Cosmology* comes from the award-winning educators and historians at the Center for History of Physics of the American Institute of Physics. The history is presented in "Ideas" and "Tools" sections. With more than 35,000 words and 380 striking illustrations, this is the most complete web exhibit of its kind.

FOR KIDS!!!

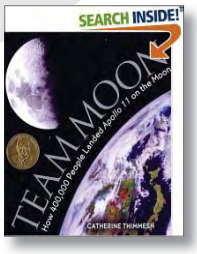


Kingfisher Pocket Guide to the Night Sky. James Muirden. Kingfisher, 2006. 176 pp., Paperback, $6.95. *www.kingfisherpub.com*

This practical guide to the night sky is a must for young astronomers. Packed with information on the Sun and Moon, the constellations, the solar system, the Milky Way, and beyond, it offers advice and ideas for how to get the most out of studying the night sky. Written by an expert in astronomy, this handy guide is full of facts and figures, diagrams, charts and tables, star maps, and moon charts —everything needed for a night of scientific adventure! For grades 5 through 9.

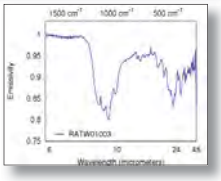
Space Launch! Series. Helen and David Orme. Gareth Stevens, Inc., 2007. Set of 12 books, 24 pp. each, Hardcover, $203.40. *www.garethstevens.com*

Space Launch! ignites young readers' interest in science by presenting facts about our solar system in a dynamic and colorful format. From the earliest discoveries to the latest space missions, students will gain essential knowledge about the Sun, the known planets, our Moon, asteroids and comets, and other bodies in space. For grades 2 and up.



Team Moon: How 40,000 People Landed Apollo 11 on the Moon. Catherine Thimmesh. Houghton Mifflin, 2006. 80 pp., Hardcover, $19.95. *www.houghtonmifflinbooks.com*

Here is a rare perspective on a story we only thought we knew. Apollo 11, the first Moon landing, is a story that belongs to many, not just the few and famous. It belongs to the seamstress who put together 22 layers of fabric for each space suit. To the engineers who created a special heat shield to protect the capsule during its fiery reentry.To the flight directors, camera designers, software experts, suit testers, telescope crew, aerospace technicians, photo developers, engineers, and navigators. Gathering direct quotes from some of these folks who worked behind the scenes, Thimmesh reveals their very human worries and concerns. Culling NASA transcripts, national archives, and stunning NASA photos from Apollo 11, she captures not only the sheer magnitude of this feat but also the dedication, ingenuity, and perseverance of the greatest team ever — the team that worked to first put man on the Moon. For grades 4 through 7.



Rock Around the World Rock Identification. Service provided by the Mars Space Flight Facility, Arizona State University. *ratw.asu.edu*

Mars scientists are asking students from around the world to help them understand the Red Planet. Send in a rock collected by you or your classroom from your region of the world, and a special tool like the one on the Mars Exploration Rovers will be used to determine what it's made of. A picture of the rock will be posted on the web and a report will be generated indicating what kind of rock it is. Rocks sent in are kept in a special collection where scientists from around the world can study them. Details about how to submit rocks to the Mars Space Flight Facility in Tempe, Arizona, are given at the *Rock Around the World* website. Send in a rock and help the *Rock Around the World* effort!

Calendar 2007

May

4–9 Greenland Space Science Symposium, Ann Arbor, Michigan. *http://www.gsss-2007.org/*

6–10 AAS Division of Dynamical Astronomy Annual Meeting, Ann Arbor, Michigan. *http://dda.harvard.edu/*

7–9 The EarthCare Workshop, Noordwijk, Netherlands. *http://www.congrex.nl/07c08/*

10–12 3MA International Symposium: Magmatism, Metamorphism, Associated Mineralizations, Fez, Morocco. *http://www.fsdmfes.ac.ma/3MA-FES07/*

14–16 2nd IAASS Conference — Space Safety in a Global World, Chicago, Illinois. *http://www.congrex.nl/07a02/*

14–18 Molecules in Space and Laboratory, Paris, France. *http://www.u-cergy.fr/Mol_Spa_Lab/*

22–25 2007 Joint Assembly (AGU), Acapulco, Mexico. *http://www.agu.org/meetings/ja07/*

22–27 ECO Summit 2007, Beijing, China. *http://www.ecosummit2007.elsevier.com/*

24–28 26th International Space Development Conference 2007, Dallas, Texas. *http://isdc.nss.org/2007/*

27–31 AAS Solar Physics Division, Honolulu, Hawaii. *http://umbra.nascom.nasa.gov/aas_spd/*

27–01 Structure Formation in the Universe Galaxies, Stars, and Planets, Charmonix, France. *http://chamonix2007.ens-lyon.fr/*

June

11–15 Meteroids 2007, Barcelona, Spain. *http://www.spmn.uji.es/meteoroids-2007/*

14–15 Workshop on Research Enabled by the Lunar Environment, Washington, DC. *http://www7.nationalacademies.org/ssb/LunarRT2007.html*

19–22 Second Volcano-Ice Interaction on Earth and Mars Conference, Vancouver, British Columbia. *http://volcanoes.dickinson.edu/VIWG/meetings/home.html*

19–23 Second International Workshop on Exploring Mars and its Earth Analogues, Trento, Italy. *http://irsps.sci.unich.it/education/mars07*

25–29 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica. *http://www.cenat.ac.cr/simposio/*

25–29 Extreme Solar System, Santorini Island, Greece. *http://www.astro.northwestern.edu/Santorini2007/*

25–29 Magnetospheres of the Outer Planets, San Antonio, Texas. *http://mop.space.swri.edu/*

July

2–13 IUGG XXIV General Assembly: Earth, Our Changing Planet, Perugia, Italy. *http://www.iugg.org/assemblies/2007perugia/*

8–13 Origins of Solar Systems (Gordon Conference), South Hadley, Massachusettes. *http://www.grc.org/programs.aspx?year=2007&program=origins*

9–12 37th International Conference on Environmental Systems, Chicago, Illinois. *http://www.sae.org/events/ice/*

9–13 Seventh International Conference on Mars, Pasadena, California. *http://www.lpi.usra.edu/meetings/7thmars2007*

16–20 Bioastronomy 2007: Molecules, Microbes, and Extraterrestrial Life, San Juan, Puerto Rico. *http://www.ifa.hawaii.edu/UHNAI/bioast07.htm*

18–21 NewSpace 2007, Washington, DC. *https://www.space-frontier.org/Events/NewSpace2007/*

23–27 Nuclear Astrophysics: Beyond the First 50 Years, Pasadena, California. *http://www.na2007.caltech.edu/*

30–Aug 4 Asia Oceania Geosciences Society 2007, 4th Annual Meeting, Bankok, Thailand. *http://www.asiaoceania.org/aogs2007/*

August

11–18 2007 NASA Planetary Volcanology Field Workshop: Analogs to Martian Volcanic Features in High Spatial Resolution Data, Kilauea Volcano, Hawai'i. *http://www.higp.hawaii.edu/~harold/volcano_wkshop/*

13–15 Workshop on Ices, Oceans, and Fire: Satellites of the Outer Solar System, Boulder, Colorado. *http://www.lpi.usra.edu/meetings/icysat2007/*

13–17 70th Annual Meeting of the Meteoritical Society (MetSoc 2007), Tucson, Arizona. *http://www.lpi.usra.edu/meetings/metsoc2007/*

19–23 American Chemical Society 234th National Meeting and Exposition, Boston, Massachusetts. *http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=meetings%5cboston2007%5chome.html*

19–24 17th Annual Goldschmidt Conference (Goldschmidt 07), Cologne, Germany. *http://www.goldschmidt2007.org/*

20–24 15th Conference on Air-Sea Interaction and the 14th Conference on Middle Atmosphere, Portland, Oregon.
http://www.ametsoc.org/meet/fainst/200715isa14m.html

27–31 A Century of Cosmology: Past, Present and Future. S. Servolo (Venice), Italy.
http://cosmology2007.brera.inaf.it/

27–31 Second International Conference on Earth System Modelling, Hamburg, Germany.
http://www.mpimet.mpg.de/fileadmin/static/icesm/

September

10–13 From the Sun Towards the Earth: Living with a Star, Boulder, Colorado.
http://www.lmsal.com/lws2007/

22–26 Bridging the Gap II: Effect of Target Properties on the Impact Cratering Process, Saint-Hubert, Canada.
http://www.lpi.usra.edu/meetings/gap2007/

24–27 Astrophysics in the Next Decade, Tucson, Arizona.
http://cadcwww.dao.nrc.ca/cadcbin/get_meetings?meeting_no=2096

October

3–6 Hothouse, Icehouse, and Impacts: The Late Eocene Earth, Monte Conero (Ancona), Italy.
http://geosociety.org/penrose/07italy.htm

7–12 39th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Association (DPS 2007), Orlando, Florida.
http://www.aas.org/dps/meetings.html

22–26 Exoplanets: Detection, Formation, and Dynamics, Suzhou, China. *http://iaus249.nju.edu.cn/*

25–27 Space Resources Roundtable IX, Golden, Colorado.
http:/www.ISRUinfo.com

28–31 GSA Annual Meeting: Earth Sciences for Society, Denver, Colorado.
http://www.geosociety.org/meetings/2007/

November

5–7 Workshop on the Chronology of Meteorites and the Early Solar System, Kauai, Hawai'i.
http://www.lpi.usra.edu/meetings/metchron2007/

6–7 Workshop on Planetary Atmospheres, Baltimore/Washington, DC Area.
http://www.lpi.usra.edu/meetings/patm2007/

12–16 European Mars Science and Exploration Conference (EMSEC): Mars Express and ExoMars, Noordwijk, The Netherlands.
http://www.rssd.esa.int/index.php?project=TOP&page=conf_mars07

December

10-14 Fall Meeting of the American Geophysical Union, San Francisco, California.
http://www.agu.org/meetings/

January 2008

22–25 Chapman Conference on Solar Wind Interaction with Mars, San Diego, California.
http://www.agu.org/meetings/chapman/2008/acall/

22–25 Terrestrial Planets: Evolution Through Time, Ahmedabad, India.
http://www.prl.res.in/~djconf08/