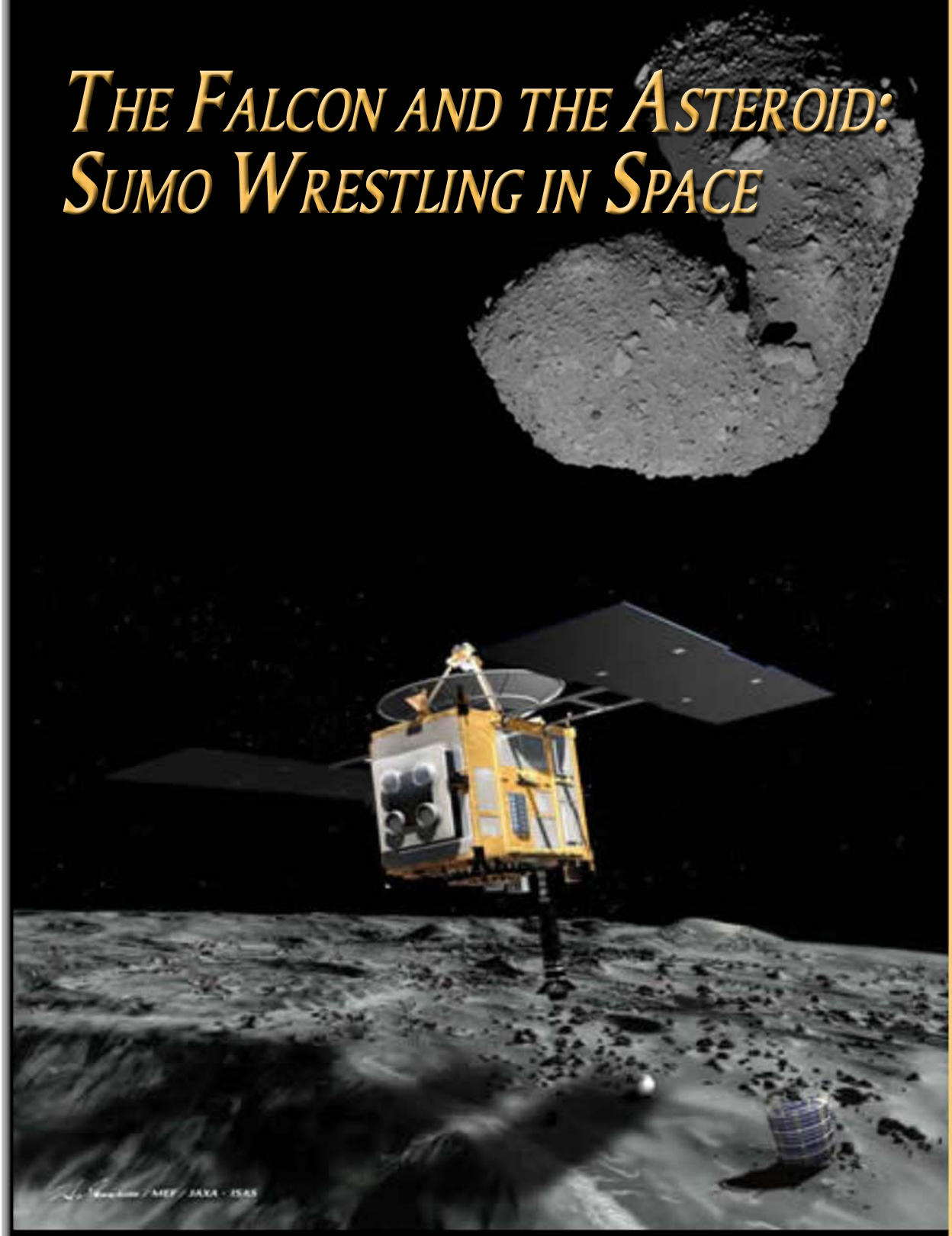
The Falcon and the Asteroid: Sumo Wrestling in Space



Contents

Lunar and Planetary Information

BULLETIN

December 2005
Issue 104

Lunar and Planetary Institute — Universities Space Research Association

www.lpi.usra.edu/lpib

The Falcon and the Asteroid: Sumo Wrestling in Space

Dr. Paul Schenk, Editor
Lunar and Planetary Institute

In deep space, a mechanical bird named Hayabusa has been wrestling with a small lumpy asteroid named Itokawa since September. The outcome of this match is still undecided, but the results so far have planetary scientists quite happy. Conceived and launched by the Japanese Aerospace Exploration Agency (JAXA), Hayabusa (Japanese for "falcon") is one of the most ambitious missions flown beyond the Moon.

Itokawa, named after a pioneering Japanese rocket scientist, is a member of the near-Earth asteroid family and may be related to some of the meteorites that fall to Earth each year. Equipped with imaging cameras, an altimeter, and X-ray and infrared spectrometers, Hayabusa has been designed to retrieve small grains of dust and rock from the surface by gently touching the surface of the asteroid, firing a small projectile into the surface, and hopefully blasting bits of rock and dust into the onboard sampling chamber. Once safely off the surface, the sample would be stowed into the reentry capsule for return to Earth in the summer of 2007. The plan is audacious.

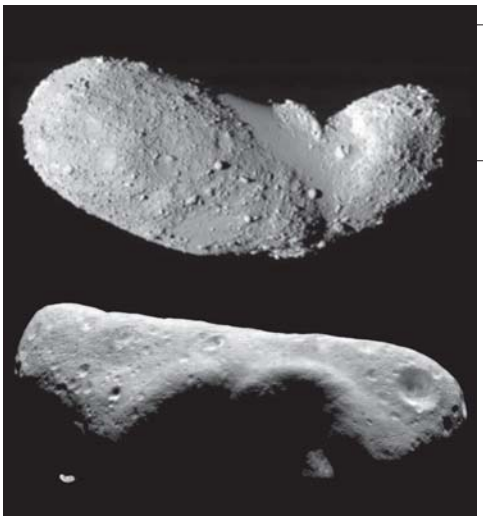
Artist's rendering showing the Hayabusa spacecraft on final approach to the surface of an asteroid. The long narrow tube extending from the base of the solar-powered spacecraft is the sampling funnel, designed to collect fragments from the surface. Credit: Japanese Aerospace Exploration Agency (JAXA).

Itokawa is very oblong and looks like a bent bowling pin with a skin condition. Because Itokawa is only 700 meters (approximately 0.5 miles) long and 305 meters (1000 feet) across at its widest, we could walk around it in less than an hour, if we could keep from drifting off the surface into space. The task of landing and picking up a piece of soil on such a small object in space is not easy. The lack of significant gravity doesn't help conserve fuel during landing; it actually requires the spacecraft to continually "nudge" its way toward the surface, using radar to sense its distance to the surface. Compounding this difficulty is the very irregular shape and rough surface of Itokawa. Hayabusa must avoid being hit by the long end of the asteroid as it rotates, which is a little like trying to land on a moving blimp with a helicopter in a wind storm.

The two months leading up to the landing included two practice runs. These rehearsals revealed several software issues that required correction to ensure a successful landing. Hayabusa also attempted to deposit onto the surface a miniature robot called Minerva that would estimate temperatures and take a few pictures. An anomaly resulted in the robot lander being released as Hayabusa was moving away from Itokawa. The minuscule gravitational force of the asteroid was not sufficient to pull Minerva back to the surface, so it drifted away.

On November 26 (JST), Hayabusa successfully touched down briefly on the surface of Itokawa and completed its sampling sequence. Now we must wait to see if any fragments of the asteroid were actually captured by the probe. Contact with Hayabusa was established, but problems with the spacecraft thrusters remain unresolved as of this writing. It is not yet clear if there is sufficient fuel and control to return the samples to Earth, tentatively scheduled for summer 2007 in Australia. These samples could help determine whether any of the meteorites currently on Earth can be traced directly to observed asteroids. (This was one of the goals of the Near Earth Asteroid Rendezvous mission to asteroid Eros in 2001, although that mission did not solve this puzzle as it did not return or analyze the surface directly.)

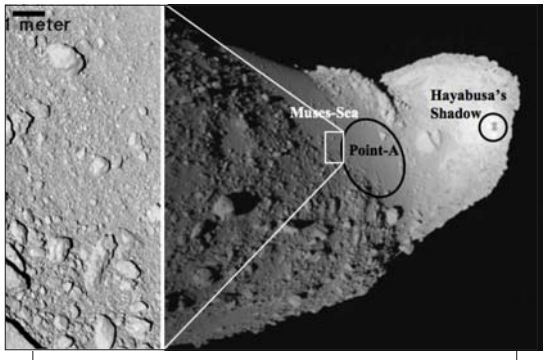
In preparing to retrieve samples, Hayabusa also mapped the surface of Itokawa in great detail. What it saw was totally unexpected. Previous spacecraft encounters with asteroids Gaspra, Ida, Mathilde, and Eros showed irregularly shaped bodies with smooth but heavily cratered surfaces. Tiny Itokawa, on the other hand, is covered in angular and coarse boulders and rocks several meters wide, the largest being up to 20 meters (66 feet) across. Only two smooth areas similar



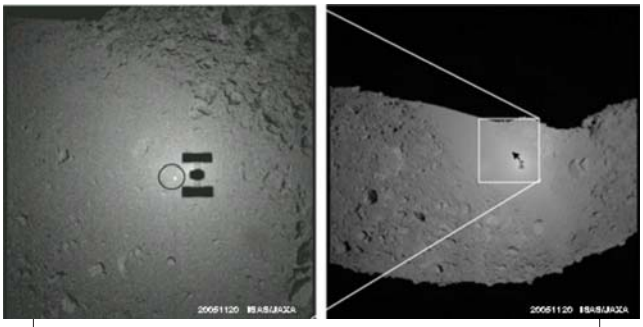
The surface of Itokawa (top) is covered in meter-sized rocks and boulders. Other asteroids, including Eros (shown at bottom), are generally smooth and covered in powdery regoliths. The small bright spot at bottom left shows how Itokawa compares in actual size to Eros, which is 33 kilometers (21 miles) long. Itokawa is actually less than 1 kilometer (0.6 miles) long.

to what was observed on Eros were found, and these were near the rotational poles. This presented a challenge to mission controllers in Japan, who naturally expected to see a surface more like Eros. Any large rock could impact the spacecraft during landing and ruin the attempt to retrieve samples. One of these two smooth areas, Muses Sea, was selected as a sampling site.

The extremely rocky surface also poses a scientific challenge. Why is the surface of this asteroid so different from the others we have observed, and why are there almostno craters? One clue may be its very small size. Less than one-fiftieth the size of Eros, this body may be very young and may not have developed the fine powdery regolith (or soil) common to asteroids. Or the regolith may have been stripped off by sunlight or knocked off by an impact event. With a surface gravity one-millionth that of Earth, any dust knocked off would be unlikely to return, possibly preventing the formation of a regolith



These views show one of the primary landing sites for Hayabusa, whose shadow is visible on the surface at right. Muses Sea is one of the few smooth spots on the surface, shown at high resolution at left. Most of the large rocks in this closeup view are about 1 meter (3 feet) across.



High-resolution view of Itokawa taken during a rehearsal landing attempt in November. Hayabusa's shadow is clearly visible. The small bright spot outlined by the black circle is a marker left on the surface by the spacecraft. This marker served as a homing target during the landing on November 26.

Boulders are present on other asteroids, but Itokawa is literally covered by rocks and boulders. Is this what other asteroids would look like if we stripped away the powdery surface covering? Are the interiors of all asteroids comprised of small angular fragments like we see on Itokawa? Whatever the final outcome of this sumo match in space, asteroid scientists will have many exciting new results to debate and analyze for the next several years as they work to answer these questions. Even if returning the samples to Earth proves impossible, Hayabusa can be considered a great success for Japan's planetary exploration program.

News From Space

NASA's Pluto Space Probe Begins Final Launch Preparations as the Planet Itself Continues to Surprise

NASA's New Horizons spacecraft arrived at the Kennedy Space Center, Florida, in September for final preparations and testing for the probe's decade-long journey. It will be the first spacecraft to visit Pluto and the Kuiper belt and is scheduled to launch on a Lockheed Martin Atlas V rocket in January 2006. New Horizons recently completed four months of space-environment tests at NASA's Goddard Space Flight Center and at the John Hopkins University Applied Physics Laboratory, where it was designed and built.

Carrying seven scientific instruments, the compact probe will fly by Pluto and Charon as early as summer 2015. Its mission is to characterize the global geology and geomorphology of the bodies, map their surface compositions, record temperatures, and examine Pluto's complex atmosphere. In October, the mission team received good news from the Department of Energy (DOE), which had completed its thermal vacuum testing of the radioisotope thermoelectric generator (RTG). Encounter power output will be 200 watts, which is better than promised, and significantly higher than the 182-watt minimum requirement. The extra power will help maximize science return when the spacecraft reaches a target Kuiper belt object, after its Pluto encounter.

Artist's impression of the New Horizons spacecraft encountering a Kuiper belt object. The Sun, more than 4.1 billion miles (6.7 billion kilometers) away, shines as a bright star embedded in the glow of the zodiacal dust cloud. Jupiter and Neptune are visible as orange and blue "stars" to the right of the Sun. Although you would not actually see the myriad other objects that make up the Kuiper belt because they are so far apart, they are shown here to give the impression of an extensive disk of icy worlds beyond Neptune. Credit: Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute (JHUAPL/SwRI).

Workers at Kennedy Space Center's Payload Hazardous Servicing Facility lower the New Horizons spacecraft onto a spin table with the help of an overhead crane. The spacecraft underwent a spin test as part of prelaunch processing.

In November, mission simulations and autonomy testing were performed on the spacecraft and spacecraft simulator. In December, hydrazine fuel for attitude control and course correction maneuvers will be loaded, and the engineering team will perform the final spin balance tests and "dress" the spacecraft out for flight. The flight-ready spacecraft will then be transported to the launch pad for hoisting onto the Atlas V launch vehicle.

Following final launch approval, liftoff is scheduled for January 11, 2006, during a two-hour launch window that opens at 2:07 p.m. EST. Launch windows are available daily through February 14, 2006. Principal investigator Alan Stern of the Southwest Research Institute in Boulder, Colorado, leads the New Horizons science and mission team.

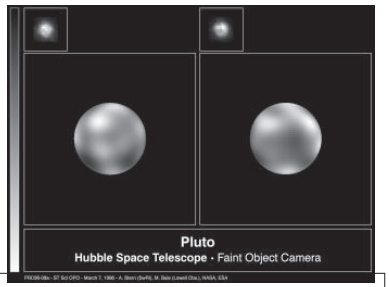
The National Research Council ranked the first reconnaissance of Pluto and the Kuiper belt at the top of its priority list for planetary missions this decade. A closeup look at these mysterious bodies will provide new information about the origin and evolution of our solar system.

Meanwhile, Pluto continues to provide surprises, a hopeful harbinger for exciting discoveries in 2015. Using NASA's Hubble Space Telescope, astronomers discovered Pluto may have not one, but three moons. If confirmed, the discovery of the two new moons could offer insights into the nature and evolution of the Pluto system, Kuiper belt objects with satellite systems, and the early Kuiper belt. The Kuiper belt is a vast region of icy, rocky bodies beyond Neptune's orbit. Pluto was discovered in 1930. Charon, Pluto's only confirmed moon, was discovered by groundbased observers in 1978. The planet resides about 3 billion miles from the Sun in the heart of the Kuiper belt.

"[This discovery] means planetary scientists will have to take these new moons into account when modeling the formation of the Pluto system," said Stern. It will also double the number of objects that the mission will have for investigation in 2015.

The candidate moons, provisionally designated S/2005 P1 and S/2005 P2, were observed approximately 27,000 miles away from Pluto. The objects are roughly two to three times as far from Pluto as Charon. The team plans to make follow-up Hubble observations in February to confirm the newly discovered objects are truly Pluto's moons. Only after confirmation will the International Astronomical Union consider names for S/2005 P1 and S/2005 P2.

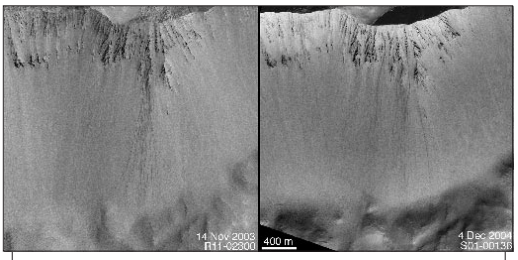
For more information about Pluto and the New Horizons mission, visit **pluto.jhuapl.edu**.



The Hubble Space Telescope took the first pictures of the surface of Pluto in 1994. The surface of Pluto is extremely cold, roughly 40° above absolute zero (–387°F or –233°C), so it seems unlikely that life could exist there. New Horizons will be the first spacecraft to visit Pluto and its moon Charon. Credit: Alan Stern (Southwest Research Institute), Marc Buie (Lowell Observatory), NASA, and ESA.

ORBITER'S LONG LIFE HELPS SCIENTISTS TRACK CHANGES ON MARS

New gullies that did not exist in mid-2002 have appeared on a martian sand dune. That's just one of the surprising discoveries that have resulted from the extended life of NASA's Mars Global Surveyor, which this month began its ninth year in orbit around Mars. Boulders tumbling down a martian slope left tracks that weren't there two years ago. New impact craters formed since the 1970s suggest changes to age-estimating models. And for three Mars summers in a row, deposits of frozen carbon dioxide near Mars' south pole have shrunk from the previous year's size, suggesting a climate change in progress. The orbiter is healthy and may be able to continue studying Mars for 5 to 10 more years.



Two Mars Orbiter Camera images, one from November 14, 2003, the other from December 4, 2004, showing boulder tracks on a crater wall. The December image shows that more than a dozen new tracks formed over the previous year. Credit: NASA/JPL/Malin Space Science Systems.

The orbiter's longevity has enabled monitoring of year-to-year patterns on Mars, such as seasonal dust storms and changes in the polar caps. "Mars is an active planet, and over a range of timescales changes occur, even in the surface," said Dr. Michael Malin of Malin Space Science Systems, San Diego, principal investigator for the Mars Orbiter Camera on Mars Global Surveyor.

Two gullies appear in an April 2005 image of a sand-dune slope where they did not exist in July 2002. The Mars Orbiter Camera team has found many sites on Mars with fresh-looking gullies, and checked back at more than 100 gullied sites for possible changes between imaging dates, but this is the first such find. Some gullies, on slopes of large sand dunes, might have formed when frozen carbon dioxide, trapped by windblown sand during winter, vaporized rapidly in spring, releasing gas that made the sand flow as a gully-carving fluid.

At another site, more than a dozen boulders left tracks when they rolled down a hill sometime between the taking of images in November 2003 and December 2004. It is possible that they were set in motion by strong wind or by a "marsquake," Malin said.

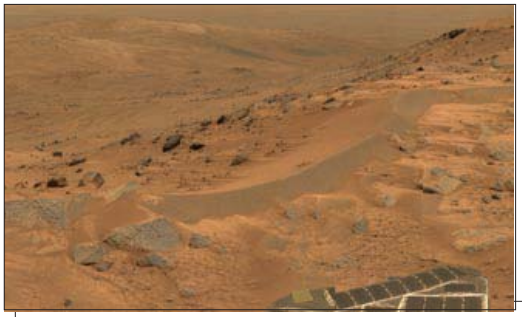
Some changes are slower than expected. Studies suggest new impact craters might appear at only about one-fifth the pace assumed previously, Malin said. That pace is important because crater counts are used to estimate the ages of Mars' surfaces.

The camera has recorded seasonal patterns of clouds and dust within the atmosphere over the entire planet. In addition, other instruments on Mars Global Surveyor have provided information about atmospheric changes and year-to-year patterns on Mars as the mission has persisted. Daily mapping of dust abundance in Mars' atmosphere by the Thermal Emission Spectrometer has shown dust over large areas during three Mars southern hemisphere summers in a row. However, the extent and duration of dust storms varied from year to year.

For newly released images, visit
www.nasa.gov/vision/universe/solarsystem/mgs-092005-images.html and **www.msss.com/mars_images/moc/2005/09/20/**.

NASA'S DURABLE SPIRIT SENDS INTRIGUING NEW IMAGES FROM MARS

Working atop a range of martian hills, NASA's Spirit rover is rewarding researchers with tempting scenes filled with evidence of past planet environments. "When the images came down and we could see horizon all the way around, that was every bit as exhilarating as getting to the top of any mountain I've climbed on Earth," said Chris Leger, a rover planner at NASA's Jet Propulsion Laboratory (JPL). The summit sits 82 meters (269 feet) above the edge of the surrounding plains. It is 106 meters (348 feet) higher than the site where Spirit landed nearly 20 months ago. Spirit and twin rover, Opportunity, successfully completed their three-month prime missions in April 2004. They have inspected dozens of rocks and soil targets since then, continuing their pursuit of geological evidence about formerly wet conditions on Mars.



This mini-panorama was taken by Spirit on August 23, 2005, just as the rover finally completed its intrepid climb up "Husband Hill." The summit appears to be a windswept plateau of scattered rocks, little sand dunes, and small exposures of outcrop. Credit: NASA/JPL-Caltech/Cornell.

"Spirit has climbed to the hilltop and looked over the other side, but NASA did not do this just to say we can do it. The Mars rovers are addressing fundamental questions about martian history and planetary environments," said NASA's Mars Exploration Program Director Doug McCuistion. The crest of "Husband Hill" offers Spirit's views of possible routes into a basin to the south with apparently layered outcrops. Shortly after Spirit landed, it observed a cluster of seven hills about 3 kilometers (2 miles) east of its landing site. NASA proposed naming the range "Columbia Hills" in tribute to the last crew of space shuttle Columbia. The tallest of the hills commemorates Rick Husband, Columbia's commander.

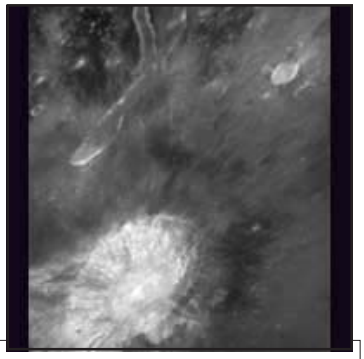
Volcanic rocks covering the plain Spirit crossed on its way to the hills bore evidence of only slight alteration by water. When Spirit reached the base of the hills five months after landing, it immediately began finding rocks with wetter

histories. "This climb was motivated by science," said Steve Squyres of Cornell University, Ithaca, New York. Squyres is principal investigator for the rovers' science instruments. "Every time Spirit has gained altitude, we've found different rock types. Also, we're doing what any field geologist would do in an area like this: climbing to a good vantage point for plotting a route."

The landing site and the Columbia Hills are within Gusev Crater, a bowl about 150 kilometers (95 miles) in diameter. "We're finding abundant evidence for alteration of rocks in a water environment," said Ray Arvidson of Washington University, St. Louis, Missouri. Arvidson is deputy principal investigator for the rovers' science instruments. "What we want to do is figure out which layers were on top of which other layers. To do that it has been helpful to keep climbing for good views of how the layers are tilted to varying degrees. Understanding the sequence of layers is equivalent to having a deep drill core from drilling beneath the plains."

Both Spirit and Opportunity have been extremely successful. Their solar panels are generating plenty of energy thanks to repeated dust-cleaning events. Spirit has driven 4827 meters (3.00 miles), and Opportunity 5737 meters (3.56 miles). For images and information about the rovers and their discoveries, visit **www.nasa.gov/vision/universe/solarsystem/mer_main.html** or **marsrovers.jpl.nasa.gov**.

NASA's Hubble Looks for Possible Moon Resources



The Hubble Space Telescope Advanced Camera for Surveys imaged Aristarchus Crater and nearby Schroter's Valley rille on August 21, 2005. The images reveal fine-scale details of the crater's interior and exterior in ultraviolet and visible wavelengths. These new observations will be used to quantify abundances of ilmenite, a titanium-bearing oxide of potential value as a resource for human exploration of the Moon. Credit: NASA/ESA/J. Garvin (NASA Goddard).

NASA is using the unique capabilities of the Hubble Space Telescope for a new class of scientific observations of Earth's Moon. Hubble's resolution and sensitivity to ultraviolet light have allowed the telescope to search for important oxygen-bearing minerals on the Moon. Since the Moon does not have a breathable atmosphere, minerals, such as ilmenite (titanium and iron oxide), may be critical for a sustained human lunar presence. Ilmenite is a potential source of oxygen for breathing or powering rockets.

The new Hubble observations are the first high-resolution, ultraviolet images ever acquired of the Moon. The images provide scientists with a new tool to study mineral variations within the lunar crust. As NASA plans future expeditions to the Moon, such data, in combination with other measurements, will help ensure the most valuable sites are targeted for robotic and human missions. "These observations of the Moon have been a challenging and highly successful technological achievement for NASA and the Hubble team, since the telescope was not originally designed for lunar observations," said Jennifer Wiseman, program scientist for the Hubble at NASA Headquarters. "The images will inform both scientific studies of lunar geology and future decisions on further lunar exploration," she said.

With the new Hubble images, scientists are comparing the properties of the rock and soil samples from the Apollo sites, as well as studying the Aristarchus impact crater, which neither humans nor robotic spacecraft have visited. The Hubble observations of Aristarchus Crater and Schroter's Valley will help refine researchers' understanding of the diverse, scientifically interesting materials in the region and unravelling their full resource potential. "Our initial findings support the potential existence of some unique varieties of oxygen-rich glassy soils in both the Aristarchus and Apollo 17 regions. They could be well suited for visits by robots and human explorers in efforts to learn how to live off the land on the Moon," said Jim Garvin, chief scientist at NASA's Goddard Space Flight Center. Garvin is principal investigator for the project. For more information and images, visit **hubblesite.org/news/2005/29**.

NASA Discovers Life's Building Blocks are Common in Space

NASA Spitzer Space Telescope image of the spiral galaxy M81, located some 12 million light years from Earth. The infrared radiation emitted by polycyclic nitrogen-containing aromatic hydrocarbon (PANH) molecules is shown in red. This emission is excited by star (and planet) formation along the edges of the spiral arms. Credit: NASA/JPL-Caltech/S. Willner (Harvard-Smithsonian Center for Astrophysics).

In October, a team of NASA exobiology researchers revealed that organic chemicals that play a crucial role in the chemistry of life are common in space. "Our work shows a class of compounds that is critical to biochemistry is prevalent throughout the universe," said Douglas Hudgins, an astronomer at NASA's Ames Research Center. Hudgins is principal author of a study detailing the team's findings that appears in the October 10 issue of the *Astrophysical Journal*.

"NASA's Spitzer Space Telescope has shown complex organic molecules called polycyclic aromatic hydrocarbons (PAHs) are found in every nook and cranny of our galaxy. While this is important to astronomers, it has been of little interest to astrobiologists, scientists

who search for life beyond Earth. Normal PAHs aren't really important to biology," Hudgins said. "However, our work shows the lion's share of the PAHs in space also carry nitrogen in their structures. That changes everything."

"Much of the chemistry of life, including DNA, requires organic molecules that contain nitrogen," said team member Louis Allamandola, an astrochemist at Ames. "Chlorophyll, the substance that enables photosynthesis in plants, is a good example of this class of compounds, called polycyclic aromatic nitrogen heterocycles, or PANHs. Ironically, PANHs are formed in abundance around dying stars. So even in death, the seeds of life are sewn," Allamandola said.

The NASA team studied the infrared "fingerprint" of PANHs in laboratory experiments and with computer simulations to learn more about infrared radiation that astronomers have detected coming from space. They used data from the European Space Agency's Infrared Space Observatory satellite. High-resolution images are available at **www.nasa.gov/centers/ames/multimedia/images/2005/spitzer.html**.

For more information about this research, visit **www.astrochem.org/PANHS.html**.

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 **January 9, 2006**. 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**.

To be added to the postal mailing list to receive notification by postcard of future issues, please send your name, address, and phone to LPIB Notifications, 3600 Bay Area Blvd., Houston TX 77058-1113, USA.

ISSN 1534-6587

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,
*Production Editor (**dotson@lpi.usra.edu**)*

In Memoriam

Alastair G. W. Cameron

Alastair G. W. Cameron, 80, one of the great astrophysicists of the twentieth century, died of heart failure in Tucson, Arizona, on October 3. Cameron was born in 1925 in Winnipeg, Manitoba and spent his professional life seeking to unlock the fundamental mysteries of the universe, the stars, and the solar system. His public service influenced the course of the U.S. planetary exploration program over the past few decades.

Cameron did fundamental research in astrophysics, planetary sciences, and meteoritics. He was among the first to develop the theory of nucleosynthesis — the production of the chemical elements in stars — and to advocate that the formation of the Moon resulted from a giant impact on the early Earth by an object at least the size of Mars.

A scholar, researcher, advisor, editor, and distinguished member and fellow of many prestigious and leading scientific organizations and associations, Cameron was a member of the U.S. National Academy of Sciences and a fellow of the American Academy of Arts and Sciences and of the Royal Society of Canada. He was also a fellow of the American Association for the Advancement of Science, the Meteoritical Society, and the American Geophysical Union.

Cameron spent 26 years of his academic career at Harvard University beginning in 1973 as associate director for planetary sciences at the Harvard-Smithsonian Center for Astrophysics and, later, as head of Harvard's astronomy department. He was named professor emeritus at Harvard University and appointed the Donald H. Menzel Research Professor of Astrophysics in 1999, a position he held at the time of his death. At the time of his death he was also a senior research scientist in the Lunar and Planetary Laboratory at the University of Arizona. He was a member of the Arizona Senior Academy in Tucson, which is a nonprofit organization devoted to life-long learning, thinking, and doing.

Cameron's research interests included nucleosynthesis and associated areas of nuclear physics, stellar evolution, supernova explosions, neutron stars, star and planet formation, physics of planets, and planetary atmospheres. He considered the main objective of his scientific research understanding the structures and origins of astronomical objects and systems. He became a leader and innovator in the application of emerging computer technology for solving astrophysics problems.

Cameron was a champion for academic freedom and a proponent for government funding to support basic research as a means to further technical development and applied research in many areas of knowledge, including the sciences. Among his many awards and medals of recognition for his contribution to the sciences was the R. M. Petrie Prize Lecture Award from the Canadian Astronomical Society in 1970; the NASA Distinguished Public Service Medal, awarded in 1983; the J. Lawrence Smith Medal from the National Academy of Sciences in 1988; the Harry H. Hess Medal from the American Geophysical Union in 1989; the Leonard Medal from the Meteoritical Society for his outstanding contributions to the science of meteoritics in 1994; and the Russell Lecturer prize from the American Astronomical Society, awarded to him in 1997 for a lifetime of preeminence in astronomical research. Five days before his death, Cameron was notified that he had also been named the 2006 recipient of the Hans A. Bethe prize from the Division of Nuclear Physics of the American Physical Society "for his pioneering work in developing the fundamental concepts of nuclear astrophysics."

Photograph courtesy of the Center for Astrophysics at Harvard University. Most of the text for this article was provided by the Lunar and Planetary Laboratory of the University of Arizona.

Spotlight on Education

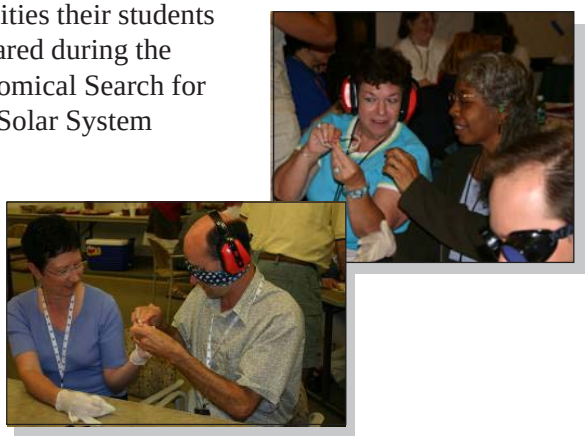
"Spotlight on Education" highlights events and programs that provide opportunities for space scientists to become involved in education and public outreach and to engage science educators and the community. If you know of space science educational programs or events that should be included, please contact the South Central Organization of Researchers and Educators at **score@lpi.usra.edu**.

Success, Inclusion for All, Lasting Collaborations Exceptional Needs Workshop V

"Time to listen, time to share, time to experience . . ." The fifth annual Exceptional Space Science Materials for Exceptional Students Workshop V (ENWS V) was a huge success, bringing together a wonderful group of educators, education specialists, and NASA personnel. The workshop was organized and sponsored by the Southeast Regional Clearinghouse (SERCH), one of NASA's Science Mission Directorate's Space Science Support Network Broker Facilitators.

The Exceptional Needs workshops, part of the Support Network's Special Needs Initiative, familiarize product developers with the diversity of exceptional classroom and audience needs and acquaint educators of exceptional students with the wide variety of standards-based space science educational support materials available from NASA. This year's workshop, held in Huntsville, Alabama, on July 24–28, 2005, focused on visions of success, inclusion techniques, and lasting collaborations. During the workshop, participants heard keynote addresses and plenary lectures from some outstanding individuals: Mike Kersjes, author of "A Smile As Big As the Moon: A Teacher, His Class and Their Unforgettable Journey," discussed the strength and comfort that comes from teamwork; Nancy Hendrix and Don Pierce, educators from Arkansas, talked about ways in which the educational community can use NASA materials in an exceptional classroom and the importance of motivating and believing in exceptional students; Robert Shelton, a NASA scientist who is blind, discussed the strides that he has made in making NASA products accessible to everyone; and Bac Shelton, an art instructor with cerebral palsy, talked about his life and how having individuals who believed in him made the difference.

Participants evaluated four products while simulating the different disabilities their students and/or museum and science-center audiences may have. The activities shared during the workshop were developed by each of NASA's education forums: Astronomical Search for Origins and Planetary Systems, Structure and Evolution of the Universe, Solar System Exploration, and Sun-Earth Connection. Participants provided constructive feedback on modifications to make the products more accessible. Finally, the attendees were provided with opportunities to discuss their own exceptional needs work via a poster session, as well as network and form some lasting collaborations. ENWS V was such a triumph because of the team of participants and their dedication to and passion for this effort of making products available to all children! As one speaker said, a TEAM will always succeed, because "Together Everyone Achieves More!"



Scientists Communications and Involvement Working Group

Are you a space scientist interested in becoming more involved in education and public outreach (E/PO)? The Scientists Communications and Involvement Working Group (SCIWG) of the Science Mission Directorate's Space Science Support Network works to build the community and capacity of scientists contributing to E/PO. SCIWG supports this community in their diverse outreach efforts through convened education presentations, sessions, and workshops at scientific conferences; development and presentation of information, research, and resources pertinent to scientist involvement in education; and consultation on projects involving scientists in E/PO.

SCIWG hosts four-day workshops for scientists, engineers, and E/PO managers and other professionals working to engage scientists in education. Attendees increase their knowledge of educational opportunities and challenges and strengthen existing E/PO programs through enhanced understanding of audience needs, best practices, leveraging, and evaluation. To receive workshop announcements, join the mailing list at **http://www.spacescience.org/education/workshops_1.html**.

The Scientists in Education Web site (**http://www.scientistsineducation.org**) hosts extensive resources for scientists interested in E/PO efforts, including profiles of researchers involved in E/PO, overviews of successful E/PO proposals, and papers exploring the roles open to scientists and reasons why involvement is important. Interested scientists can join the Education and Public Outreach Partner Directory, a community-supported directory that promotes new partnerships between people working to integrate scientific research and education, and can sign up to receive the quarterly ROSIE (Regional Opportunities for Scientists in Education) newsletter.

STARDUST SAMPLES EN ROUTE TO EARTH

Launched in February 1999 and successfully rendezvousing with Comet Wild 2 in January 2004, the Stardust mission (**http://stardust.jpl.nasa.gov/**) will reach its next milestone in January 2006, when the sample return capsule parachutes to Earth's surface. The capsule contains samples of interstellar dust, remnants from the formation of our solar system, that will provide scientists with information about the formation and evolution of our Sun and planets in our solar system.

The mission has several resources for educators (**http://stardust.jpl.nasa.gov/classroom/educators.html**), including fact sheets, models, and *Think Small in a Big Way*, an educator's guide of classroom activities for grades 5–8. Information about Stardust workshops, held at selected sites across the nation, is provided at the Web site.

SPACE DAY 2006 DESIGN CHALLENGES

Lockheed Martin's 2006 Space Day Design Challenges encourages students in grades 4–8 to explore "Living and Working on the Moon" through a variety of topics, including creating a well-balanced meal in a leak-proof, spill-proof package; developing a mechanical device that permits space travelers to retrieve out-of-reach objects; and maintaining an expedition journal. The deadline for submission is **February 1, 2006,** and registration is required. Classrooms, clubs, and homeschool groups are invited to participate. Stellar Design Challenge teams will be selected by the Space Day Educational Advisory Committee and will be recognized at the Space Day Opening Ceremony on Thursday, May 4, 2006, in Washington, DC. Spark children's interest in space science by getting involved in the design challenges! For more details, and other information about Space Day and Space Day events, visit **http://www.spaceday.org**.

ASTROBIOLOGY IN THE CLASSROOM

AstroVenture

AstroVenture is an online, interactive collection of activities designed for classroom use with children in grades 5–8. The activities explore astrobiology through modules in astronomy, geology, atmospheric science, and biology. Students can chat with NASA scientists, have online collaborations, and role-play NASA occupations as they search for and design a planet habitable by humans. For more information, visit **http://astroventure.arc.nasa.gov/**.

Astrobiology Poster

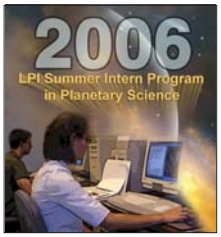
Liven up classroom walls with NASA's recent astrobiology poster! The poster explores what life is, where it is, and how we are searching for it. Activities and resource suggestions accompany the poster. A downloadable version of the poster, along with accompanying classroom activities and handouts, is available at **http://nai.arc.nasa.gov/poster/index.cfm**.

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 **http://science.hq.nasa.gov/research/ecosystem.htm**.

Research Opportunities for Students

A number of institutions provide internships in the planetary sciences. Various areas of research are available from the diverse list below.

Lunar and Planetary Institute Summer Intern Program



The Lunar and Planetary Institute invites undergraduates to experience cutting-edge research in the planetary sciences through its Summer Intern Program. As a Summer Intern, students work one-on-one with a scientist at the LPI or at the NASA Johnson Space Center to complete a research project of current interest in planetary science. The Summer Intern Program allows participants to experience a real research environment, to learn from top-notch planetary scientists, and to preview careers in research. The 10-week program runs from June 5, 2006, to August 11, 2006. Interns receive a $500 per week stipend to cover living expenses and assistance with travel expenses to a maximum of $1000. Shared low-cost housing in apartments near the LPI can be arranged.

The LPI is located near Johnson Space Center, on the south side of Houston, Texas. The LPI provides, on NASA's behalf, leadership in the scientific community for research in lunar, planetary, and solar system sciences, and linkage with related terrestrial programs. The deadline for applying to the LPI Summer Intern Program is **January 20, 2006**. More information can be found at ***www.lpi.usra.edu/lpiintern/***.

Planetary Geology and Geophysics Undergraduate Research Program

NASA provides funding for 8 weeks of summer undergraduate research for up to 12 qualified applicants. Selected students work closely with a NASA investigator to learn the details of research in planetary geosciences. The deadline for applying to the PG&GURP is **January 30, 2006**. More information can be found at ***www.acsu.buffalo.edu/~tgregg/pggurp.html***.

Arkansas Center for Space and Planetary Sciences Summer Research Internship

The Arkansas Center for Space and Planetary Sciences sponsors a NASA-supported summer research program for undergraduate science and engineering majors. Students in chemistry, physics, biology, electrical engineering, geosciences, and mechanical engineering are especially encouraged to apply. In this 10-week program, students will carry out research in astrobiology, astronomical processes, mission design and engineering, planetary atmospheres, and planetary geology and geophysics.

Participants will receive a stipend of $3500. Accommodations will be provided by the program. Both dormitory and off-campus housing is available. In addition, $500 in travel support will be allotted for each participant to attend a national or regional conference during the academic year following the period of summer research. To complement their research experience, participants will engage in a weekly seminar program and several field trips, including a visit to the NASA Johnson Space Center (expenses paid by program). The program will end with a meeting during the final week of the program at which participants will present the results of their summer projects. The deadline for applying to the ACSPS Summer Research Internship is **February 28, 2006**. More information can be found at ***spacecenter.uark.edu/97.htm***.

Mars Flight Project Internship Program

The Mars Program Office at the Jet Propulsion Laboratory has released the first request for applications for Mars Flight Project Internships. The program is an oustanding opportunity for science and engineering students to contribute to current Mars flight projects and become part of the next generation of scientists. Interns will work at the Jet Propulsion Laboratory directly with Mars scientists and engineers on the Mars Reconnaissance Orbiter mission. Initial internships will be on a full-time basis for a six-month period from March 2006 to September 2006. The application deadline is **December 30, 2005**. To access the online application form, or to obtain more information about the program, go to ***www.sop.usra.edu/mars_intern/***.

Additional Student Research Opportunities

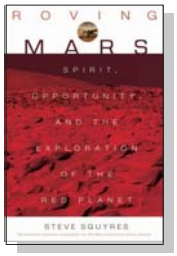
There are many other institutions providing student research opportunities. A few are listed below.

Carnegie Institution of Washington Geophysical Laboratory — ***www.gl.ciw.edu/interns/***
Smithsonian Astrophysical Observatory — ***hea-www.harvard.edu/REU/REU.html***
National Air and Space Museum — ***www.nasm.si.edu***
National Museum of Natural History (Department of Mineral Sciences) — ***www.nmnh.si.edu/minsci/***

New and Noteworthy

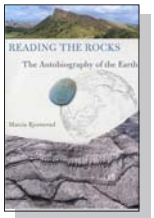
These products are available from booksellers or the publisher listed.
Please note that the LPI does not offer these products through its Order Department.

Books



Roving Mars: Spirit, Opportunity and the Exploration of the Red Planet. By Steve Squyres. Hyperion Books, 2005. 434 pp., Hardcover, $25.95. **www.hyperionbooks.com**

Dr. Steve Squyres, the face and voice of NASA's Mars Exploration Rover mission, dreamed up the mission in 1987, saw it through from conception in 1995 to a successful landing in 2004, and serves as the principal scientist of its $400 million payload. He has gained a rare inside look at what it took for the rovers Spirit and Opportunity to land on the Red Planet in January 2004 — and knows firsthand their findings. Combining the journey of a young scientist with the history of NASA's Mars space program, *Roving Mars* offers a dramatic account of one of the most amazing adventures of our time. In a conversational and compelling voice, Squyres goes into detail about how the MER mission was born, covering the politics, mistakes, and confusion that ensued, and presents the technical aspects of the mission in a way that is accessible to the most unscientifically minded among us. Squyres leads us through the exhausting and exhilarating race to get the rovers to the launchpad in time, and finally, the amazing story of the journey of Spirit and Opportunity to Mars and what they found there.

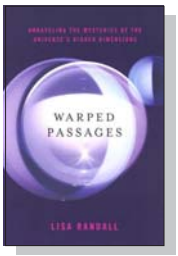


Reading the Rocks: The Autobiography of the Earth. By Marcia Bjornerud. Basic Books, 2005. 237 pp., Hardcover, $26.00. **www.perseusbooksgroup.com**

To many of us, Earth's crust is a relic of ancient, unknowable history. But to a geologist, stones are richly illustrated narratives, telling gothic tales of cataclysm and reincarnation. For more than four billion years, in beach sand, granite, and garnet schists, the planet has kept a rich and idiosyncratic journal of its past. Fulbright Scholar Bjornerud takes the reader along on an eye-opening tour of Deep Time, explaining in elegant prose what we see and feel beneath our feet. Both scientist and storyteller, Bjornerud uses anecdotes and metaphors to remind us that our home is a living thing with lessons to teach. She shows how our planet has long maintained a delicate balance, and how the global give-and-take has sustained life on Earth through numerous upheavals. But with the rapidly escalating effects of human beings on their home planet, that cosmic balance is being threatened — and the consequences may be catastrophic. Containing a glossary and detailed timescale, as well as vivid descriptions and historic accounts, *Reading the Rocks* is literally a history of the world, for all friends of Earth.

Theaters of Time and Space: American Planetaria, 1930–1970. By Jordan D. Marché II. Rutgers University Press, 2005. 266 pp., Hardcover, $49.95. **rutgerspress.rutgers.edu**

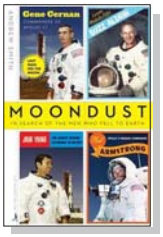
Every year, millions of Americans visit planetariums and are captivated by their strikingly realistic portrayals of the night sky. Today, it is difficult to imagine astronomy education without these magnificent celestial theaters. But projection planetariums, first developed in Germany, have been a part of American museum pedagogy only since the early twentieth century and were not widespread until the 1960s. Former planetarium director and historian of science Marché offers the first complete account of the community of individuals and institutions that, during the period between 1930 and 1970, made planetariums the popular teaching aids they are today. The book addresses issues such as the role of gender and social developments within the planetarium community, institutional patronage, and the popularization of science. Offering an insightful, wide-ranging look into the origins of an institution that has fascinated millions, *Theaters of Time and Space* brings new perspectives to how one educational community changed the cultural complexion of science, helped shape public attitudes toward the U.S. space program, and even contributed to policy decisions regarding allocations for future space research.



Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions. By Lisa Randall. Ecco, 2005. 512 pp., Hardcover, $27.95. **www.harpercollins.com**

The universe has its secrets. It may even hide extra dimensions, different from anything ever imagined. A whole raft of remarkable concepts now rides atop the scientific firmament, including parallel universes, warped geometry, and three-dimensional sinkholes. We understand far more about the world than we did just a few short years ago, and yet we are more uncertain about the true nature of the universe than ever before. Have we reached a point of scientific discovery so advanced that the laws of physics as we know them are simply not sufficient? Will we all soon have to accept explanations that previously remained in the realm of science fiction? Randall takes us into the incredible world of warped, hidden dimensions that underpin the universe we

live in, describing how we might prove their existence, while examining the questions that they still leave unanswered. Warped *Passages* provides an overview that tracks the arc of discovery from early twentieth-century physics to the razor's edge of today's particle physics and string theory, unweaving the current debates about relativity, quantum mechanics, and gravity.



Moondust: In Search of the Men Who Fell to Earth. By Andrew Smith. Fourth Estate, 2005. 384 pp., Hardcover, $24.95. **www.harpercollins.com**

Twelve astronauts made the greatest of all journeys — to the Moon — during the Apollo era, and all were indelibly marked by it. *Moondust* reveals the stories of the nine men still alive who were caught between the gravitational pull of the Moon and Earth's collective dreaming. These astronauts, trained by NASA for every eventuality in deep space, were completely unprepared for the fame that resulted from being in the center of the enormous global media event that was the Apollo program. Possibilities bloomed, and marriages crumbled under the strain. And the world was changing, too — the wild and happy experimentations of the 1960s gave way to the cynicism and self-doubt of the 1970s. How could they find the meaning of life after Apollo when the biggest adventure they could possibly have was a memory? Some traded on past glories, others tried to move on. Some found God; some sought oblivion. Some reinvented themselves and discovered a measure of happiness in a completely unexpected place. A thrilling blend of history, reporting, and memoir, *Moondust* rekindles the hopeful excitement of an incandescent hour in American history and captures the bittersweet heroism of those who risked everything to hurl themselves out of the known world, and who were never again quite able to accept its familiar bounds.

DVD

Beyond the Moon: Failure is Not an Option 2 DVD. Presented by the History Channel, 2005. 100 minutes, one disc, $29.95. **store.aetv.com/html/home/index.jhtml**

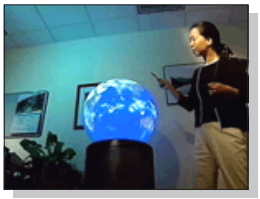
In May 1961, President Kennedy set a goal for the nation: Beat the Russians to the Moon, and do it within the decade. In July 1969, NASA met that goal. But no one ever defined what should happen next. In 1969, the engineers of Mission Control assume that America's great push would continue: a moon base, shuttle, space station, manned flights to Mars, etc. But as a growing number of political, social and economic problems vie for the nation's attention — and money — Congress, Presidents, and the American public are not so sure. Is manned space flight really worth the cost? Is it worth the risk? To some, answers to these questions remain unclear even today. But for legendary flight director Gene Kranz and the men and women of Mission Control, there is no doubt. Despite waning public support and shrinking budgets, they still have a job to do, a job where lives hang in the balance and there is no room for error. *Beyond the Moon: Failure is Not an Option 2* tells the little-known story of America's post-Apollo space program, from the point of view of the engineers of Mission Control. Through their experiences, we get a firsthand look at life inside Mission Control, as these driven engineers continue to push the boundaries of space flight from 1972 into the new century.

MISCELLANEOUS

STS-107 Mural Memorial Poster. Available from The Space Store, 2005. $15.95. **www.thespacestore.com**

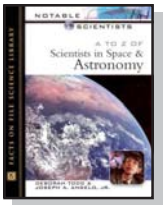
On February 1, 2003, the space shuttle Columbia (STS-107) and her crew were lost over the western United States during reentry into Earth's atmosphere. To honor our fallen heroes, artist Richard Wood created oil on canvas portraits of the STS-107 crew, which became part of an 8' × 16' mural memorial. The Painting an Empty Sky Project mural was created by art students in the Clear Creek Independent School District and the children of the astronauts of the space shuttle Columbia. The poster includes the names of the astronauts along with the words "The world sees them as heroes — Clear Creek I.S.D. and the NASA Community knew them as family." Proceeds of the sale of this poster go to the Clear Lake High School Art Department.

Magic Planet® Digital Video Globe. www.globalimagination.com
(contact company for system pricing information)



The Magic Planet® by Global Imagination is a digital video display globe with a durable acrylic sphere-shaped screen. Digital displays include planetary, Earth, and a variety of other images. Magic Planet® globes range in size from 14 inches to 6 feet in diameter, with smaller globes affording portability and larger globes providing maximum stunning impact. The Magic Planet® comes in both portable and pedestal configurations, each with a tailored finish. Portable units — perfect for use in classrooms, meeting rooms, or boardrooms — can be carried by a single individual, and set up for a presentation alongside a notebook computer. Pedestal configurations are ideal for standing exhibits or displays, such as in museums, executive briefing centers, and corporate lobbies. Also available for use with the Magic Planet® is StoryTeller™software, content and services that presents global information and global context in the most compelling way possible. The Magic Planet® can be configured to meet the diverse needs of public, private, and government organizations.

FOR KIDS!



Notable Scientists: A to Z of Scientists in Space & Astronomy. By Deborah Todd and Joseph A. Angelo Jr., Facts on File, 2005. 322 pp., Hardcover, $45.00. www.factsonfile.com

Designed for middle- and high-school students, this book is an ideal reference to notable male and female scientists in the field of space and astronomy, from antiquity to the present. Containing more than 150 entries and approximately 50 black-and-white photographs, this volume in the Notable Scientists series emphasizes these scientists' contributions to the field as well as their effects on those who have followed. A general introduction explains who is included in the book and why, and several indexes list scientists by field of specialization, nationality, subject area, and chronology. A bibliography and an index round out this comprehensive reference. For grades 6 and up.

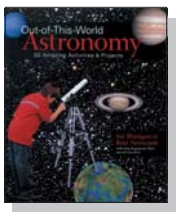
Star Rocket. From Scientific Explorer. $21.95. www.scientificexplorer.com

The new Star Rocket streaks up to 200 feet in the sky! It's the latest advancement in our patented baking soda and vinegar rocket technology. We've carefully engineered this powerful flyer for maximum performance thrills. The Star Rocket takes only a few minutes to assemble, and you can launch it again and again! The experiments included are a great introduction to chemistry and physics. You'll find out whether balsamic vinegar makes better fuel than regular vinegar, and you can test different fin and fuselage configurations for optimum aerodynamics. It's a fun and unforgettable flying experience. For ages 8 and up.

Space Planes. By Andrew Dewar. Tuttle Publishing, 2004. 96 pp., Paperback, $15.95.
www.tuttlepublishing.com

Space Planes takes us away from Earth and explores the futuristic machines that fly in space. With a mix of classic space planes and original designs, and featuring the exciting stories of our journey into space, this book is an exciting addition to the Paper Airplanes That Really Fly! series. Detailed instructions are included for building 15 space plane models — the space shuttle, the North American X-15, SpaceShipOne, Starliner, Mercury, Space Taxi, Luna, Jupiter, Shooting Star, Constellation, Hannibal, the Orbital Sciences X-34, the X-30 Orient Express, Pluto, and Whirligig. Totally cool and unique, this book is a must for enthusiasts and anyone who's ever loved flying.

Out-of-This-World Astronomy. By Joe Rhatigan, Rain Newcomb, and Greg Doppmann. Lark Books, 2005. 128 pp., Paperback, $12.95. www.larkbooks.com



What are stars? Why does the Moon change shape? Budding astronomers will find answers to all their questions about the night sky — and far more — in these 50 eye-opening activities. Three hundred color photos and illustrations, some from NASA's magnificent collection, help kids soar out into the solar system and get their bearings among the stars. Youngsters will learn to use binoculars and telescopes, and how to chart their viewing highlights in a stargazing notebook. A photographic trip to the Moon will inspire kids to map its many phases, calculate a person's lunar weight, and find out what happens during an eclipse. Voyaging farther out also reveals why the other planets wouldn't make a good home for humans, and will help children understand why Earth is a very special place. This is an out-of-this world introduction to astronomy for children grades 5–8.

Calendar 2005–2006

Information was valid as of this issue's publication and is subject to change without notice. For more information see the Web sites listed.

December

5–9 AGU Fall Meeting, San Francisco,California.
http://www.agu.org/meetings/fm05/

7–9 Annual Convention and Meeting on Earth System Processes Related to Earthquakes and Tsunamis and Volcanic Eruptions, Hyderabad, India.
http://www.igu.in/schedule.htm

16 GRSG Annual Meeting: Advances in Geological Remote Sensing, London, England.
http://www.grsg.org/meeting.html

January 2006

8–12 American Astronomical Society, Washington, DC.
http://www.aas.org/meetings/meeting_dates.html

9–12 44th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada. *http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=778&viewcon=submit*

9–12 Chapman Conference on Jets and Annular Structures in Geophysical Fluids, Savannah, Georgia.
http://www.agu.org/meetings/cc06acall.html

29– Feb. 2 86th American Meteorological Society Annual Meeting, Atlanta, Georgia.
http://www.ametsoc.org/meet/annual

February

16–20 AAAS Annual Conference, St. Louis, Missouri.
http://www.aaas.org/meetings/Annual_Meeting/

March

5–8 Earth & Space 2006, League City, Texas.
http://www.asce.org/conferences/space06/

6–10 SCOSTEP 11th Quadrennial Solar Terrestrial Physics Symposium "Sun, Space Physics and Climate," Rio de Janeiro, Brazil.
http://www.abc.org.br/scostep2006/

14–18 37th Lunar and Planetary Science Conference, League City, Texas.
http://www.lpi.usra.edu/meetings/lpsc2006

14–18 The 2nd European Space Weather Week, Noordwijk, The Netherlands.
http://www.estec.esa.nl/wmwww/wma/events.html

April

2–7 European Geosciences Union, Vienna, Austria.
http://www.meetings.copernicus.org/egu2006/

3–6 22nd National Space Symposium, Colorado Springs, Colorado.
http://www.spacesymposium.org/national06/

9–12 AAPG 2006 Annual Convention, Houston, Texas.
http://www.aapg.org/houston/index.cfm

May

1–5 ASPRS 2006 Conference, "Prospecting for Geospatial Information Integration," Reno, Nevada.
http://www.asprs.org/reno2006/

7–15 Dynamical Processes in Space Plasmas, Beer-Sheva, Israel.
http://physics.bgu.ac.il/~gedalin/Isradynamics/

8–12 First International Conference on Impact Cratering in the Solar System, Noordwijk, The Netherlands.
http://www.rssd.esa.int/index.php?project=TOP&page=craters

14–17 Geological Association of Canada Annual Meeting, Montreal, Canada.
http://www.gac.ca/ANNMEET/annmeet.html