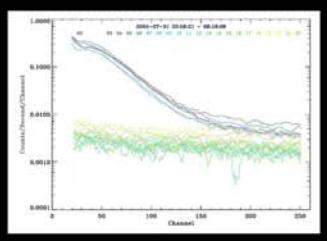
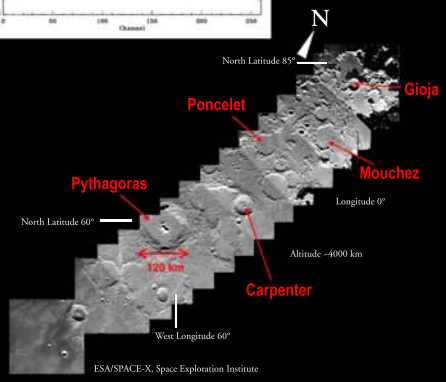
SMART 1 — Europe at the Moon





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Lunar and Planetary Information

BULLETIN

Lunar and Planetary Institute — Universities Space Research Association

February 2005
Issue 101

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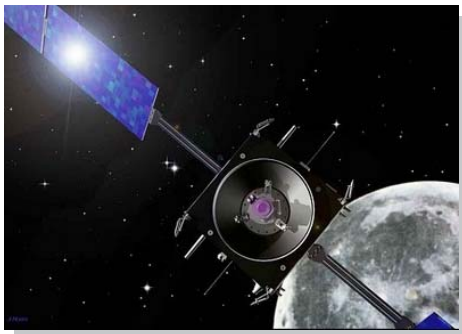
SMART 1— EUROPE AT THE MOON

— Benjamin Bussey, Applied Physics Laboratory of The Johns Hopkins University

The SMART-1 spacecraft is currently in an elliptical orbit around the Moon, and is about to begin a six-month data acquisition campaign during which its diverse suite of instruments will improve our understanding of the Moon. Even before this mapping begins, however, SMART-1 is already a success, as its 15-month journey to the Moon tested the applicability of a new type of propulsion for future deep space missions.

HISTORY

SMART-1 is the first of a possible series of Small Missions for Advanced Research and Technology (SMART). These missions are intended to test new technologies that will be utilized by future larger missions. The second SMART mission, SMART-2, has been announced and will launch in 2006 to test drag-free technology for use by the Laser Interferometer Space Antenna (LISA) and Darwin missions. These missions are also intended to be relatively low-cost. The primary goal for SMART-1 is to test a solar electric primary propulsion system for its applicability on the larger "cornerstone" mission BepiColombo, which will use this type of propulsion on its journey to Mercury early in the next decade. A secondary goal of the SMART-1 mission is to test a suite of miniaturized instruments. Initial plans for SMART-1 designated it as an asteroid mission rather than a lunar one. Fortunately for lunar scientists, the decision was made in 1999 for SMART-1 to be redirected to a lunar orbital mission.



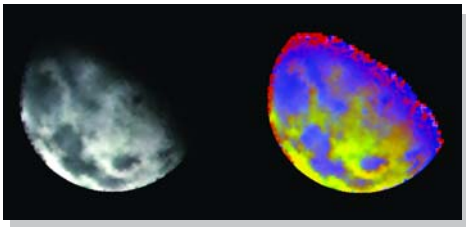
Artist's impression, courtesy of ESA.

THE ENGINE

SMART-1 uses an Hall Effect thruster to get to the Moon. These engines generate low thrust but use very little fuel. The thrust to fuel ratio (called "impulse") is typically higher than for standard chemical propulsion systems. This means that less fuel mass is required, resulting in the ability to carry more payload. The downside is that the low thrust means that the spacecraft takes longer to finish its journey. The main use of solar electric propulsion is for deep space missions where journey time is potentially less important; these type of engines will allow for more scientific instruments to be carried. The SMART-1 engine has an impulse that is between five and seven times higher than typical chemical propulsion systems. The engine will use approximately 80 kilograms of xenon fuel during the mission's lifetime.

THE INSTRUMENTS

The Moon is more than just a destination for the electric propulsion spacecraft. SMART-1 carries a suite of lightweight instruments that will provide new insight into our understanding of the Moon.



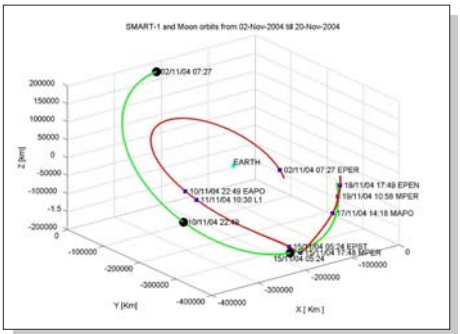
How SIR will map minerals of the Moon.

SMART-1 will look at the lunar surface at a wide variety of wavelengths. The Advanced Moon Micro-Imager (AMIE) camera is a lightweight camera (1.8 kilograms) that will take images using its 1024 × 1024 sensor in the visible and near infrared. The SMART-1 Infrared Spectrometer (SIR) is a spot spectrometer that looks in the 900–2400-nanometer range with spatial resolutions as high as 300 meters/pixel. The Demonstration of a Compact Imaging X-ray Spectrometer (D-CIXS) will conduct high-resolution X-ray spectroscopy to provide surface composition maps of key elements. Associated with D-CIXS is the X-Ray Solar monitor (XSM), which will measure the Sun's X-rays at the same time as D-CIXS is looking at the Moon, thus helping to calibrate the D-CIXS data. The Spacecraft Potential, Electron and Dust Experiment (SPEDE) will measure the solar wind. Lunar libration will be studied by the Radio Science for SMART-1 (RSIS) experiment.

In addition to scientific instruments, SMART-1 will also test new technologies. The Electric Propulsion Diagnostic Package (EPDP) will monitor the health of the solar electric engine. This will provide useful feedback for the design of engines to be used by future spacecraft. New communication technologies will be tested by the Ka-band Telemetry and Telecommand Experiment (KATE). The SMART-1 laser link experiment will demonstrate the feasibility of optical communication at Earth-Moon distances. Optical communication has the potential to greatly increase the data volumes that can be returned by space missions. Finally, the Onboard Autonomous Navigation (OBAN) experiment will test new techniques that will allow spacecraft to navigate through space with less help from Earth.

SMART 1 — Europe at the Moon

The Journey



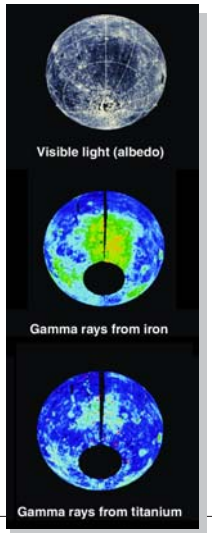
SMART-1 and Moon orbits.

SMART-1 began its journey on September 27, 2003, onboard an Ariane-5 rocket launched from the Ariane launch complex in French Guiana. SMART-1 was one of the first spacecraft to execute a unique type of launch, the Ariane Structure for Auxiliary Payloads (ASAP) launch. The SMART-1 spacecraft was attached to an adaptor ring that sat below the main paying customer. Essentially, SMART-1 got a free (or to be more accurate, inexpensive) ride into space, which is the main benefit of being a secondary payload. The downside to such a launch is that it is the primary paying customer who chooses the exact launch date, therefore requiring flexibility in the launch schedule of the secondary payload. Fortunately, because of its use of solar electric propulsion, the launch schedule for SMART-1 had a great deal of flexibility. After launch, SMART-1 began continuously thrusting, spiraling out from Earth by slowly increasing the apogee of its orbit. Finally, after several months SMART-1 began to feel the pull of the Moon's gravity and its engine was used to spiral toward the Moon. This long cruise phase was not wasted, with several instruments making scientific observations. On November 15, 2004, SMART-1 entered into a lunar orbit, after a journey of almost 14 months.

Science at the Moon

Now that SMART-1 has arrived at the Moon, the serious business of acquiring scientific data will begin. The final mapping orbit is elliptical with closest approach to the lunar surface happening at the south pole with the spacecraft at an altitude of 300 kilometers. Apolune over the north pole is at 3000 kilometers (*Apolune* is the point in the path of a body orbiting the Moon that is farthest from the center of the Moon; *Perilune* is the point that is nearest). SMART-1's plan is to map the Moon for six months.

The AMIE camera will acquire both multispectral and single-band images of the lunar surface. At perilune, when the spacecraft is only 300 kilometers above the lunar surface, the resolution of AMIE is 27 meters/pixel, making it equivalent to the Clementine high-resolution camera at the lunar poles. AMIE will therefore be able to vastly improve the current high-resolution coverage of the south polar region. Conversely, the highest altitude of 3000 kilometers occurs over the north pole. Here the AMIE resolution is 270 meters/pixel and the field of view of the clear filter portion of the sensor is 139 kilometers, meaning that AMIE has the capability of taking snapshots of the illumination conditions in the area surrounding the Moon's north pole. If the length of the SMART-1 mission is extended, AMIE will be able to see how the lighting near the north pole changes during one entire seasonal variation. This lightweight camera uses an innovative method of obtaining multispectral images. In order to minimize its size, instead of using a filter wheel, the filters are placed directly over the sensor with different areas either having a clear filter or narrowband filters covering 750, 915, and 960 nanometers. A small area is sensitive to 847 nanometers light and is used in the laser link experiment.



X-ray survey of the Moon.

The SIR is a spot spectrometer that will obtain high-spectral-resolution (6-nanometer) spectra in the 0.9–2.4-micrometer range with spatial resolutions as high as 300 meters/pixel. This spatial resolution is high enough to sample typical-sized homogeneous areas on the Moon. The spectral range covered includes diagnostic features of key lunar minerals. The quoted goals of this instrument include looking at compositional variations in the lunar highlands, mineralogical analysis of complex impact craters, and detailed analysis of space weathering effects.

The D-CIXS instrument will provide the first global coverage of the lunar surface in X-rays, thus generating absolute abundance maps of key elements. Under normal solar conditions D-CIXS will be able to detect magnesium, aluminum, and silicon. However, during times of increased solar activity, other elements will also be measured. Key goals of the D-CIXS instrument are to improve the estimate of the bulk composition of the Moon, and to conduct detailed studies of the lunar crustal composition. These in turn will yield insights into theories of the origin and evolution of the Moon. D-CIXS uses an innovative collimated design, thus improving the spatial resolution of its measurements. The desired spatial resolution of the final elemental maps is 50 kilometers.

Conclusions

As you read this article, SMART-1 is in orbit around the Moon and is collecting exciting new data that will improve our knowledge of the Moon's history. By the time the mission is finished we should have obtained:

- key imaging data, including more knowledge of polar lighting conditions
- the first spectrometer measurements of the lunar farside
- global high-resolution element maps from X-ray measurements

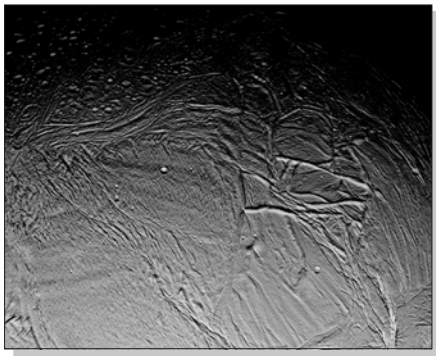
Now is an exciting time to be a lunar scientist, with SMART-1 in orbit and several missions due to launch in the next few years. SMART-1 is a great start, and we are eagerly anticipating the arrival of new data that will reshape our view of Earth's nearest neighbor.

News From Space

Mission Update: Cassini

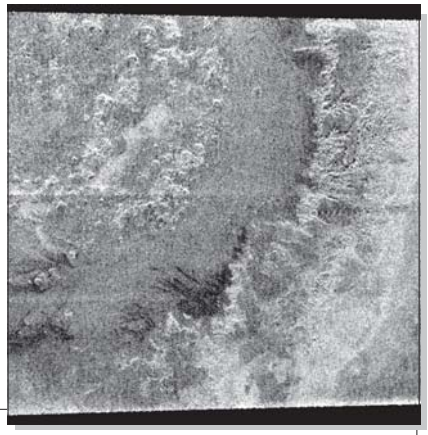
Cassini view of the northern hemisphere of enigmatic Iapetus on January 1, 2005. The image shows the boundary between the bright and dark sides of Iapetus and reveals features about 1 kilometer across.

This winter, the Cassini-Huygens mission to Saturn entered high gear. Headlined by the Huygens probe descent to Titan's surface, the mission accomplished several other primary goals, including high-resolution encounters with several of the planet's odd icy moons. Highest priority among these were Iapetus and Enceladus. Iapetus is of interest for its two-sided nature. One hemisphere is as bright as snow, the other as dark as charcoal. Cassini opened the new year on January 1 with a close pass of Iapetus at 65,000 kilometers. The new images revealed that the dark material is probably not volcanic, although what it is and how it got there will require detailed analysis and the very close encounter scheduled for September 2007. The images also revealed a curious ridge several kilometers high running along the equator of this schizoid world. Enceladus is no bigger than the state of Louisiana but has been fractured and resurfaced by ammonia lavas. It may be active today. Cassini passed within 500 kilometers of Enceladus, itself only 500 kilometers across, on February 17, and revealed multiple episodes of fracturing and craters that have been flattened by creep of ice due to high internal heat. The source of this heat remains a mystery. Closeups of Rhea, Tethys, and Mimas will come later this year.



High-resolution mosaic of Enceladus obtained February 17, 2005. These images have a resolution of 150 meters, and reveal complex fracture networks.

Titan remains a primary focus of the mission. Two radar image mosaics of the surface have been returned. These radar swaths have resolutions of approximately 400 meters, and reveal volcanic and erosional features. Impact craters have now been seen but there are very few, suggesting a young surface age. The surface of Titan is clearly geologically active, but only a fraction of the surface has been mapped to date. The big show occurred on January 14, 2005, when the European-built Huygens lander descended to Titan's surface (see "Perspective" section below). Its cameras revealed Earth-like channels and what could be shorelines. Methane apparently mists down from the atmosphere onto the surface, where it permeates the soil. The surface itself is strewn with pebbles, and the methane fluids within its soils give it a consistency not unlike mud. Clearly some erosional process is occurring on the surface and the atmosphere and surface interact in complex ways. Analysis is ongoing, and future findings will be reported at upcoming meetings, such as the special sessions to be held at the 36th Lunar and Planetary Science Conference in March (for more information, go to ***http://www.lpi.usra.edu/meetings/lpsc2005***).



Part of a radar image mosaic of Titan obtained February 15, 2005. Image shows part of a 240-kilometer-wide impact crater. Channels on the crater wall may be due to erosion.

Cassini has shown us more than just geologic units and compositional plots, however. It has also been our eyes and is treating us to panoramas straight out of science fiction. The rings and satellites seen together in space possess an ethereal beauty beyond the power of words, as can be seen by browsing through the raw and press image galleries at the Cassini Web page at ***http://saturn.jpl.nasa.gov/***.

Perspective: From the Editor's Desk

It was almost as routine as hopping the afternoon flight from New Orleans to Houston. Except this wasn't Earth, and we weren't onboard Continental Airlines. January 14, 2005. We'd been waiting 25 years, but the moment of revelation was still stunning. Saturn's large moon Titan has stood out as unusual ever since Gerard Kuiper discovered methane in its atmosphere in 1943, at the height of World War II and on the precipice of the Atomic Age and the Cold War. Voyager probed the bottom of its atmosphere 30 years later with its radio signal and the concept of ethane rain was born, despite the fact that Voyager's eyes were confounded by an enveloping orange haze. The late astronomer Carl Sagan, who brought the solar system to the homes of millions, made Titan his life's study. Now the Huygens probe has shown us Mars-like "channels" and vaguely Earth-like "shorelines," and we see a world bewildering in its somehow uncalled-for familiarity. Valleys and "seas" are not supposed to be out here a billion miles from Earth on a frigid poisonous planet, even if they were predicted by a few adventurous souls 30 years ago. Yet the landing resembled nothing so much as a routine airline flight over the tidal flats along the Gulf Coast during an autumn drizzle, complete with what appear to be droplets (of methane!) on the camera window. This impression was in no small part a result of the side-looking format of one of the descent cameras, which gave us the perspective of a tourist looking out an aircraft window; Huygens took us with it for the ride down to the alien surface.

Before last summer, Titan was considered an alien and intangible world: We could not see what it looked like or even tell how old the surface was. The rich organic stew contained in the atmosphere may bear some relation to what our own atmosphere may have been like 4 billion years ago. But Titan is not Earth. Although nitrogen is the primary gas on both worlds, methane and ethane (among other hydrocarbons) are substituted for oxygen and water. Titan's "rain" and rivers are not water but organic liquid (probably ethane), and the bedrock is not silicate rocks but water and ammonia ices. Yet, despite the alien chemistry, we now see a surface that has been eroded by fluid and has a mud-like soil (at least in one location), and precipitation (in the form of rain, mist, and/or fog), just as Mars once did and as does our own beloved Earth.

Panoramic view of Titan's surface. This view was obtained from an altitude of 20 kilometers during the descent of the Huygens entry probe on January 14, 2005.

Huygens view of the surface of Titan obtained after landing. The pebbles visible on the foreground are only a few inches across. Their rounded shapes suggest that erosion is modifying the surface of Titan.

With Huygens' descent and the Cassini orbiter's views from space (its radar and infrared instruments give us the best views; the imaging camera is still befuddled by hazes), Titan joins a short list of amazing worlds beyond Mars that can be truly called planets. The new radar views of Titan show a world of volcanos and channel networks and even a few impact craters. The volcanos of fiery Io erupt lavas in such quantity as to completely resurface that moon every few million years. Some of these lavas have compositions that have not been seen on Earth for at least 3 billion years. There is ice-capped Europa, whose deep ice-covered water ocean hides . . . — well, something. Water supports life, and not even Mars (of the distant past) or Earth have held so much water in such great abundance so near their surface. Ganymede, although geologically quiet today, has its own magnetic field and a liquid water ocean deep in its interior. Ice volcanos cover huge tracts of land and geysers vent into the thin atmosphere of Neptune's large moon Triton, a world churning away on the inside at the frozen edges of our solar system. Finally, there is cold and mysterious Pluto, with its own atmosphere; a surface of frozen nitrogen, carbon monoxide, and methane (natural gas); and a large moon. Even the smaller icy satellites confound us with their complexity. Tiny Miranda, only slightly larger than the state of Louisiana, has been convulsed by geologic resurfacing, and fractured and resurfaced Enceladus, seen by Cassini from close range on February 17 (see image on facing page), is even more strange than Miranda.

Why are these worlds relevant? They all possess features that raise them above the ordinary, features that relate to the formation and evolution of our own planet. From sulfur to ammonia volcanos to water oceans to organic rains, these worlds rock! Formerly wet Mars is currently a prime focus of planetary exploration and should be. Titan has now been raised in our consciousness to the highest levels. It must and will be the target of future exploration motivated by the desire to better understand the new discoveries and how they relate to our own origins. It will take time to understand the new findings and Cassini has completed only 3 of the planned 40 mapping encounters with Titan. It is clear already that the surface and atmosphere interact in complex ways, but we are overwhelmed with questions. Did the channels form by rain or underground seepage? How old is the surface? Are there icy volcanos active today, and what are the lavas composed of? How are the hydrocarbons in the atmosphere and on the surface formed and what is their fate? The answers will require continued intense investigation by Cassini and a return to Titan.

Titan is only part of the complex puzzle of the outer solar system. Europa and its ocean must be explored as well. True, its secrets are submerged under 10 or more miles (~20 kilometers) of ice, but the potential for organic chemistry and life in its great global sea are too great to be ignored, and Europa arguably must remain among the highest priorities for exploration beyond Mars. Global mapping and sounding and sampling of the outer ice shell all remain to be done (the Galileo mission revealed the fundamental nature of Europa but failed in its primary global mapping task, and carried no radar or landers). As Cassini and Huygens are demonstrating, thorough exploration of Europa's surface and ocean will require a landing on the surface as part of a grander strategy. Titan is revealing its secrets grudgingly, requiring virtually all of the Cassini-Huygens battery of instruments (surely a reminder that doing things right the first time is worth the investment and effort). But it is not the last major piece of terra incognita in the solar system. The large asteroids Ceres and Vesta, already known to possess unusual qualities, have yet to be mapped, and the ocean floor of Europa may hold some surprises of its own. The extremely young surface of Triton was only partially mapped. Pluto and its large moon remain unknown territory. A NASA spacecraft to be launched in 11 months should reach that frozen relic of the solar system's birth in the next decade. But even these fascinating places will not compare with Titan, which now joins that select list of worlds where the skies have opened up and rained down upon the surface. If only Carl could have been here with us to enjoy the moment.

This Huygens probe image of Titan was obtained from 20 kilometers altitude during its descent on January 14, 2005. Numerous channels are visible, suggesting that fluids (probably liquid methane) have been flowing on the surface. The airplane window has been superimposed on the original image to simulate the view we might have from a future balloon or aircraft flight over Titan!

— Dr. Paul Schenk, Lunar and Planetary Institute

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 Lunar and Planetary Institute at ***outreach@lpi.usra.edu****.*

Pre-LPSC Education and Public Outreach Workshop

This year's pre-LPSC Education and Public Outreach workshop explores "Pre-Service Teacher Preparation and the Role of the Earth and Space Science Community," and is being held immediately prior to the start of the 36th Lunar and Planetary Science Conference (LPSC).

The workshop will include presentation of pre-service program structures and models of collaboration in the Earth and space science community, discussion of how Earth and space science content is being — or can be — integrated effectively in pre-service programs, and exploration of possible roles researchers and education specialists can offer to the pre-service community. Speakers include Dr. Tim Slater, Director of the University of Arizona Science and Mathematics Center, Dr. Adriane Dorrington, Director of the NASA/Norfolk State University Pre-Service Teacher Program, and Dr. Lawrence Abraham, Co-Director of Uteach at the University of Texas at Austin.

Who should attend? Earth and space scientists, pre-service faculty, formal and informal educators, and education specialists who are interested in sharing experiences, learning more, and building collaborations.

By identifying, enabling, and leveraging partnerships, the Earth and space science community can help facilitate better preparation of science teachers, and bring the excitement of science directly into the classroom. The workshop, designed to support NASA's goal to make its science content available to all educators and students, is hosted by the Pre-Service Educators Working Group (http://www.lpi.usra.edu/education/score/pre_service.shtml), part of NASA's Science Mission Directorate's Support Network.

The workshop will be held on Sunday, March 13, 2005, from 9:00 a.m. to 4:00 p.m. at the South Shore Harbor Resort and Conference Center in League City, Texas. A light breakfast and lunch will be provided. The workshop is free, but registration is required. Participants can register using an electronic registration form provided on the LPI's Web site at ***http://www.lpi.usra.edu/meetings/lpsc2005/lpsc2005.educ.cfm***. Logistical information, including directions to South Shore Harbour, can be found on the LPSC Web site at ***http://www.lpi.usra.edu/meetings/lpsc2005***. For questions or additional information, please contact Stephanie Shipp (***shipp@lpi.usra.edu***; 281-486-2109).

Sun-Earth Day, March 20, 2005

Celebrate Sun-Earth Day — Ancient Observatories, Timeless Knowledge — by participating in a Web cast from the ancient pyramids of Chichen Itza, Mexico. Visit the Sun-Earth Day Web site at ***http://sunearthday.nasa.gov*** to learn more about the event and about how ancient cultures built structures to mark the equinoxes and solstices. Resources, information, activities, and images make the experience accessible to all visitors.

Solar Week

Educators can bring the Sun-Earth Connection into their classroom during Solar Week, February 28–March 4, 2005. The online curriculum, designed for middle-school and high-school students, explores the Sun as a star, examines its characteristics, and integrates with Sun-Earth Day. In a special effort to engage girls in science, all the researchers participating in the event are women, and careers in solar research form a topic of investigation. All students will enjoy learning more about our closest star and its influence on Earth through the classroom materials and online interactions with the scientists. For more information, visit ***http://www.solarweek.org/***.

Life at the Limits: Earth, Mars, and Beyond

Science educators are invited to participate in a NASA-sponsored field-based workshop that explores the extreme conditions in which life on Earth can thrive, and extends the observations to understanding the search for life in our solar system. The workshop, to be held July 10–17, 2005, examines the ecosystems of Nevada and California.

Middle and high school science teachers — as well as pre-service teachers, informal educators, education specialists, early college instructors, and junior college instructors — are invited to join in this hands-on, real-world experience to explore what life on Earth needs to survive, where these conditions might exist in our solar system and beyond, and how NASA is working to detect these necessary conditions and possible life.

Participants will have the opportunity to interact directly with astrobiologists and planetary scientists in the field and classroom, and will conduct hands-on, standards-based classroom and laboratory activities that can be transferred directly to students.

Share this opportunity with science educators!
For more information, visit the workshop Web site at ***http://www.lpi.usra.edu/education/fieldtrips/2005/***. Applications are due by March 23, 2005. Participants will be notified by April 8. Limited registration grants are available.

CELEBRATE SPACE DAY

The theme for this year's Space Day, May 5, celebrates the "Return to the Moon," in honor of President Bush's focus on lunar exploration. Space Day events include design challenges for students, traveling exhibits, and community outreach programs that take place on local and national levels. For information about events, educational activities, and resources, visit the Space Day Web site at ***http://www.spaceday.org/index.html***.

VOYAGES

The most recent edition of *Voyages*, the Science Mission Directorate's publication on Space Science Education and Public Outreach, is now available on line at ***http://science.hq.nasa.gov/research/newsletters.htm***. January's issue reviews the success of the Chicago 2004 conference, which focused on ways to foster broader participation in NASA Space Science Missions and Research Programs. Other educational programs and events in the NASA space science community are shared as well, including educator workshops in astronomy and the structure of the universe, student programs, and *Inside Einstein's Universe*, a program designed to be implemented in partnership between scientists and educational centers such as museums and planetariums.

HOW TO PROVIDE AN EFFECTIVE EDUCATION WORKSHOP FOR SCIENTISTS

The Space Science Institute is offering a three-day leadership workshop in Boulder, Colorado, for Education and Public Outreach leads and managers. The workshop will be held April 15–17, 2005, immediately following the NASA Astrobiology Conference. The purpose of the workshop is to provide techniques and resources for implementing workshops that will assist scientists in making meaningful and effective education and outreach contributions. For more information, contact Christy Edwards at ***edwards@spacescience.org***, or visit the Web site at ***http://www.spacescience.org/Education/ResourcesForScientists/Workshops/3_Day_2005/1_reg_new.html***.

FUNDING OPPORTUNITY

The Southeast Regional Clearinghouse (SERCH), one of NASA's Science Mission Directorate's Broker Facilitators, offers grants to support education and outreach initiatives that will increase the awareness and understanding of Earth-Sun system science, solar system research, and universe exploration. The grants are offered in collaboration with the Space Grant offices and are available only to participants in the SERCH region (states of Alabama, Arkansas, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Puerto Rico, South Carolina/Virgin Islands, Tennessee, and Virginia). SERCH is particularly interested in proposals for education and outreach efforts that support the vision and mission of NASA — NASA's Vision for Education, Science Mission Directorate (SMD) goals, and the Support Network Forums.

For more information visit the SERCH Web site at ***http://serch.cofc.edu/funding/2005opportunity.htm***. The deadline for submitting a brief letter of intent is March 28; letters can be submitted on line using an electronic form provided on the Web site (***http://serch.cofc.edu/funding/2005_intent.htm***). Proposals must be postmarked on or before May 2, 2005.

Interested in becoming more involved in space science education and public outreach? NASA's OSS 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/epo.htm***.

RESOURCES FOR RESEARCHERS

NAIF/SPICE UPDATE

The Navigation and Ancillary Information Facility (NAIF) announces availability of its Web site: ***http://naif.jpl.nasa.gov***.

The Web site provides access to most products offered by NAIF, such as SPICE kernels, the SPICE Toolkit, SPICE documentation, and SPICE tutorials. "SPICE" is the ancillary information system used by NASA's Solar System Exploration missions to determine the geometry needed for planning scientific observations, for analyzing the data returned from such observations, and for correlating results across instruments and missions (see the related article about SPICE that appeared in Issue 97).

Production of SPICE data for all currently "flying" solar system exploration missions (Mars Global Surveyor, Mars Odyssey, Mars Exploration Rover, Cassini/Huygens, Stardust, Genesis, and Messenger) is ongoing. Preparation for SPICE production for all upcoming missions (Deep Impact, Mars Reconnaissance Orbiter, DAWN, Phoenix, New Horizons, and Mars Science Lab) is in progress.

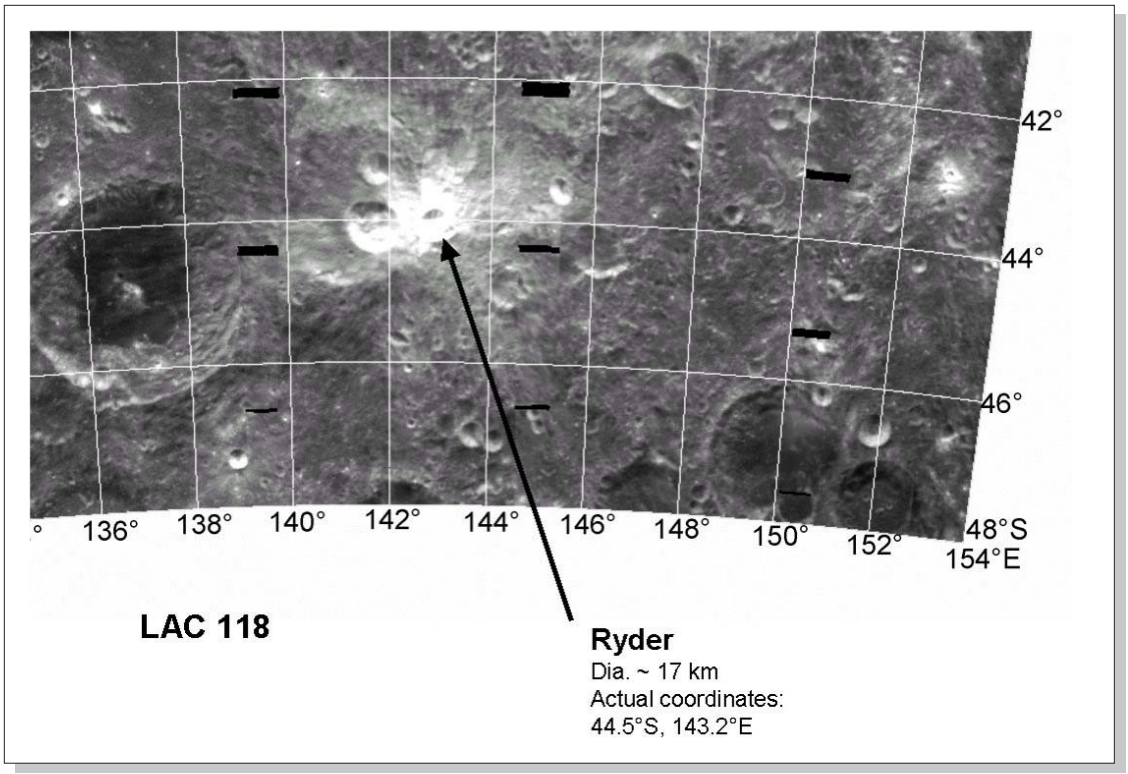
SPICE production for ESA's Mars Express, Rosetta, and SMART-1 missions is also ongoing, and the use of SPICE for Venus Express is anticipated. With the recent completion of SPICE training at Japan's Institute of Space and Astronautical Science, production of SPICE kernels for the Hayabusa and SELENE missions is now being planned.

CRATER NAMED FOR GRAHAM RYDER

A crater on the Moon has just been named after Dr. Graham Ryder, who passed away on January 5, 2002, as a result of complications from cancer of the esophagus. He was only 52 years old.

A staff scientist at the Lunar and Planetary Institute in Houston, Texas, Ryder was a premier lunar scientist who pioneered many of our most important concepts about the Moon and its evolution. Ryder's work was instrumental in several areas of lunar science. He was among the first to recognize evidence in the lunar sample collection that mare volcanism began very early, before the end of the "late heavy bombardment."

Ryder Crater is located at 44.5°S, 143.2°E. The name can now be used in publications, but remains provisional until formal approval at the IAU General Assembly in 2006.



From the Editor's Desk: Important Notice About Notification of Future Issues

Most readers are aware that we have been mailing out postcard notifications of the online publication of new issues of the *Lunar and Planetary Information Bulletin* as they are made available on our Web site (***www.lpi.usra.edu/lpib***).

If you wish to continue receiving these notifications via postcard, you must write to us at LPIB Notifications, 3600 Bay Area Boulevard, Houston TX 77058-1113, USA.

If you prefer to receive notifications of new issues via e-mail, please send a message to ***lpibeditor@lpi.usra.edu***.

Readers who do not respond by either of the methods listed above will no longer receive notification of new issues of the *Bulletin*.

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 **April 1, 2005**. Articles or announcements should be submitted via e-mail to ***lpibed@lpi.usra.edu***.

To be added to the mailing list to receive notification of future issues, please send your address (along with phone, fax, and e-mail), to LPIB Editor, 3600 Bay Area Boulevard, Houston TX 77058-1113, USA, or send an e-mail message to ***lpibed@lpi.usra.edu***.

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**)*

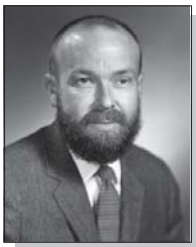
In Memoriam

Damon P. Simonelli

Damon P. Simonelli passed away unexpectedly on December 1, 2004, after collapsing at his home near Pasadena, California. Simonelli was born in the Bronx, New York, in 1959, and graduated from the Bronx High School of Science in 1976. He graduated summa cum laude in physics from Cornell in 1980, and earned a Ph.D. in Astronomy and Space Sciences under Dr. Joseph Veverka. His thesis work and early publications were on the microphysical nature of Io's surface. He went to NASA Ames as a National Research Council (NRC) Research Associate to work with Dr. James Pollack on the interiors of Pluto and Charon and the carbon budget in the outer solar system. Simonelli returned to Cornell, and with Drs. Veverka, Peter Thomas, and Paul Helfenstein, led a team to study the nature of the small, formerly uninteresting bodies of the solar system, including the inner satellites of Jupiter that were imaged by the Galileo camera. Most recently he held a Senior NRC Research Associateship with Dr. Bonnie Buratti at JPL. Simonelli was a longtime member of the Division of Planetary Sciences community, and at the 2004 meeting in Louisville presented a paper on the surface roughness of Phoebe based on Cassini VIMS observations.

Simonelli was also an avid cyclist, amateur actor, and hockey player, continuing his participation in a team even after his move from the great white north to sunny southern California. He had an encyclopedic knowledge of sports, movies, television, and science fiction, and owned a world-class collection of Star Trek and other science-fiction memorabilia. His unique and dry wit and keen scientific insights will be missed.

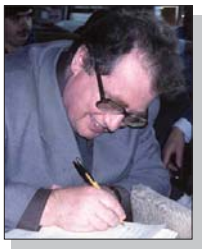
William Quaide



Dr. William Lee Quaide ("Bill" to everyone who knew him), former chief of the Planetary Science branch of NASA, died on November 10, 2004, at age 77. Quaide was a NASA scientist for 29 years, the last 16 of which he spent at NASA Headquarters as the Program Scientist for Planetary Geophysics and Geochemistry in the Solar System Exploration Division and later as Chief of the Division's Planetary Science Branch. In these positions, he played a major role in preserving the original Apollo science programs in the post-Apollo age, helping to convert them into the high-quality, durable, and exciting efforts that continue today.

After spending three years in the U.S. Navy, Quaide earned three degrees in geology from the University of California at Berkeley, including a doctorate in 1956. He spent seven years as a teacher, museum curator, and researcher before joining NASA. Quaide began his career at NASA in 1963 at the Ames Research Center, first studying the physics of craters, then analyzing lunar samples and studying the origins and histories of planetary surfaces, relocating to Headquarters in 1976. He was particularly interested in the geophysical composition of the planets, comets, and meteors in the solar system. He saw the future of NASA's deep-space exploration in unmanned rockets and satellites returning scientific information to Earth. Quaide received numerous awards during his tenure at NASA, including the Edward A. Flinn III Award from the American Geophysical Union and the Harold Masursky Award for meritorious service to planetary science from the American Astronomical Society. The asteroid named after him, 3876 Quaide, ensured that his name and legacy will live on in the solar system that he helped us to explore.

Vassili Ivanovich Moroz



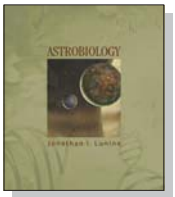
Vassili Ivanovich Moroz, 1931–2004, was a pioneer in the characterization of planetary bodies with remotely sensed data. Graduating from Moscow State University in 1954, his first job was at the Astrophysical Institute of the Academy of Sciences of the Kazakh Soviet Republic, where he built instruments and made his first observations of Mars at the favorable opposition of 1956. Returning to Moscow in late 1956, he joined I. S. Shlovsky's group at the Sternberg Astronomical Institute of Moscow State University, where he studied astronomy and astrophysics and began to develop instruments in the then-new field of infrared astronomy. Known as the "professor with the soldering iron" for his hands-on work in the laboratory, Moroz continued at the Sternberg Institute but took a joint appointment at the Space Research Institute (IKI), where he calculated reference models of the atmospheres of Venus and Mars (later expanding this research to an international scope) and established science definition plans for missions to those two planets. As the head of the infrared astronomy laboratory at IKI, Moroz developed spacecraft instrumentation for the early Mars missions, and by 1971 was getting data from an initially successful Mars 3 mission. Moroz took a leading role in establishing international cooperation in planetary exploration by his involvement first with eastern bloc countries, then France, then the U.S. When cooperative ties with the U.S. were established in the 1980s, Moroz was frequently the Soviet (later Russian) representative in annual meetings with NASA officials, and he eventually became the most influential and productive organizer in his country's program of planetary exploration. Moroz's persistent advocation for and steady support of instruments to measure reflectance properties on Mars played a critical role in the success of the OMEGA instrument currently in operation onboard the Mars Express spacecraft. Sadly, he died before the full impact of these measurements was realized.

Moroz received many honors for his scientific work, including the Soviet Red Banner Order in 1976 and the USSR State Prize in 1985. He was posthumously awarded the COSPAR Space Science Award shortly after his death in the spring of 2004. The legacy of Moroz is found in his pioneering contributions to infrared astronomy, the physics of planetary atmospheres and surfaces, his devotion to Russian science, his pivotal contributions to his country's space missions, and the students who were introduced to planetary studies in his lectures.

New and Noteworthy

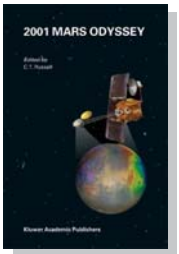
These products are available from booksellers or the publisher listed.
Please note that the LPI does not offer these products through its Order Department.

Books



Astrobiology: A Multidisciplinary Approach. By Jonathan I. Lunine. Pearson Education/Addison Wesley, 2005. 586 pp., Paperback, $68.00. ***www.aw-bc.com***

A comprehensive textbook appropriate for emerging upper-level courses in astrobiology. Internationally renowned authority Jonathan Lunine gives students with a variety of backgrounds a solid foundation in the essential concepts of physics, chemistry, biology, and other relevant sciences to help them achieve a well-rounded understanding of the fascinating study of the origin of life, planetary evolution, and life in the cosmos.

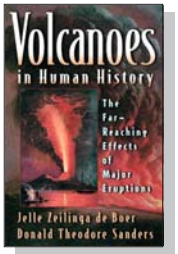


2001 Mars Odyssey. Edited by Christopher T. Russell. Kluwer Academic Publishers, 2004. 168 pp., Hardcover, $74.00. ***www.springeronline.com***

Mars, the most habitable of our sister planets, holds a special place in our imaginations and in our space exploration program. Fully half of NASA's planetary exploration effort is now devoted to Mars. Key questions include: Has Mars ever harbored life? Is there life on Mars now? Will humans be able to survive on the martian surface? Answers to these questions lie in determining the present location of water on Mars and its likely inventory in the past, and in determining the present radiation environment of Mars. The 2001 Mars Odyssey Mission contributes greatly to answering these questions by detecting near-surface water through measurements of neutron flux, from the detection of carbonates, and the quantification of its radiation environment. This book captures the objectives, the design of the mission, and the details of the instruments carried to Mars. It should be of interest to every scientist interested in participating in the ongoing exploration of Mars from graduate students to senior scientists as it provides the background information essential to interpreting the many exciting results now appearing from the mission.

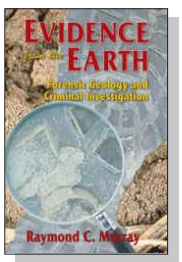
Space Tourism: Do You Want To Go? By John Spencer. Apogee Books, 2004. 220 pp., Paperback, $20.95. ***www.cgpublishing.com/apogee3.htm***

Space is only 100 miles away from anywhere on Earth. Since the early 1980s a small group of visionaries have been pioneering the frontier of off-world tourism. On April 28, 2001, American businessman Dennis Tito lifted off from Russia into Earth orbit for a week-long voyage onboard the International Space Station as the first space tourist. Today people from around the world want to go into Earth orbit to have that life-changing experience, and millions of people have had other space-themed experiences: flying in zero-gravity aircraft, visiting NASA centers and space camps, seeing IMAX space films, and going on astronomy cruises. This book examines Earth-based space tourism as a growing industry and looks at the idea of futuristic "Simexperiences" and "Simnauts."



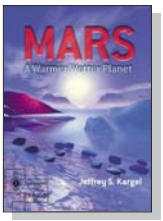
Volcanoes in Human History. By Jelle Zeilinga de Boer and Donald Theodore Sanders. Princeton University Press, 2004. 320 pp., Paperback, $18.95. ***www.pupress.princeton.edu***

This book tells the story of nine epic volcanic events, explaining the related geology for general readers and exploring myriad ways in which Earth's volcanism has affected human history. It describe in depth how volcanic activity has had long-lasting effects on societies, cultures, and the environment. After introducing the origins and mechanisms of volcanism, the authors draw on ancient as well as modern accounts — from folklore to poetry and from philosophy to literature. Beginning with the Bronze Age eruption that caused the demise of Minoan Crete, the book tells the human and geological stories of eruptions of such volcanoes as Vesuvius, Krakatau, Mount Pelée, and Tristan da Cunha. Along the way, it shows how volcanism shaped religion in Hawai'i, permeated Icelandic mythology and literature, caused widespread population migrations, and spurred scientific discovery.



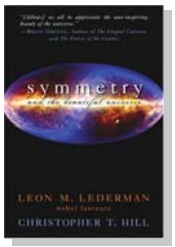
Evidence from the Earth: Forensic Geology and Criminal Investigation. By Ray Murray. Mountain Press Publishing, 2004. 240 pp., Paperback, $20.00. ***www.mtnpress.com***

CSI: Earth! The field of forensic geology — using geology techniques to aid in criminal and civil investigations — has been a stalwart in the field of criminalistics since the days of Sherlock Holmes. This book leads readers through some of the most intriguing cases involving soil and rock evidence. Along the way readers will learn about the history of forensic geology; types of rocks, soils, gemstones, and related synthetic materials; techniques for proper evidence collection and analysis; and how geologic evidence is used in court. Murray has thoroughly revised and updated his earlier work, *Forensic Geology* (published in 1975 and updated in 1992), to produce this new book.



Mars: A Warmer, Wetter Planet. By Jeffrey S. Kargel. Springer-Praxis, 2004. 288 pp., Paperback, $34.95. ***www.springeronline.com***

Long believed to have been cold, dead, and dry for eons, there is now striking new proof that not only was Mars a relatively warm and wet place in geologically recent times, but that even today there are vast reserves of water frozen beneath the planet's surface. As well as casting fascinating new insights into Mars' past, this discovery is also forcing a complete reevaluation of the mechanisms of global planetary change. What does the drastic turn of events on Mars mean for Earth's climate system? Could life have thrived on Mars very recently, and might it survive even today? Will humans be able to live off the natural resources that martian hydrogeology now seems to offer? How could Mars be transformed into the New World — and should this even be contemplated? In this absorbing, beautifully illustrated book, Kargel describes the still-unfolding revolution in our knowledge about the Red Planet and how future concepts of Mars will continue to be molded by new revelations of four billion years of geology.



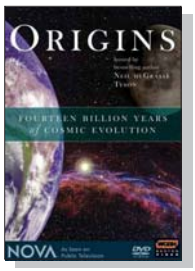
Symmetry and the Beautiful Universe. By Leon M. Lederman and Christopher T. Hill. Prometheus Books, 2004. 363 pp., Hardcover, $29.00. ***www.prometheusbooks.com***

Nobel Laureate Lederman and physicist Hill explain the elegant concept of symmetry — the eternal, ubiquitous constancy of the laws of physics — and all its profound ramifications to life on Earth and the universe in this accessible popular science book. Symmetry is the basic underlying principle that defines the laws of nature and hence controls the universe. This all-important insight is one of the great conceptual breakthroughs in modern physics and is the basis of contemporary efforts to discover a grand unified theory to explain all the laws of physics. Central to this story is an obscure but extremely gifted German mathematician named Emmy Noether, who impressed no less a scientist than Albert Einstein. In some of her earliest work she proved that the law of the conservation of energy was connected to the idea of symmetry, laying the mathematical groundwork for what may be the most important concept of modern physics. Lederman and Hill reveal concepts about the universe, based on Noether's work, that are largely unknown to the public and have wide-reaching implications in connection with the Big Bang, Einstein's theory of relativity, quantum mechanics, and many other areas of physics. Through analogies and illustrations, they bring these astounding notions to life.

Plasma Physics for Astrophysics. By Russell M. Kulsrud. Princeton University Press, 2005. 468 pp., Paperback, $45.00. ***www.pupress.princeton.edu***

Kulsrud introduces plasma physics from the ground up, presenting it as a comprehensible field that can be grasped largely on the basis of physical intuition and qualitative reasoning, similar to other fields of physics. Plasma physics appears to consist of numerous topics arising independently from astrophysics, fusion physics, and other practical applications and remains a field poorly understood even by many astrophysicists. Most of these topics can be approached from the same perspective with a simple, physical intuition. Selecting simple examples and presenting them in a simultaneously intuitive and rigorous manner, Kulsrud guides readers through a careful derivation of the results and allows them to think through the physics for themselves. Based on a course the author taught for many years, this book is intended for graduate students as well as for working astrophysicists.

DVD



Origins DVD. Presented by NOVA/PBS, 2004. 240 minutes, two-disc set, $29.95. ***www.shoppbs.org***

Has the universe always existed? How did it become a place that could harbor life? NOVA presents some startling new answers in *Origins*, a new four-part series. New clues from the frontiers of science are presented by astrophysicist Dr. Neil deGrasse Tyson. As the host of *Origins*, Tyson leads viewers on a journey to the beginning of time and to the depths of space, in search of the first stirrings of life and its traces on other worlds. Features include materials and activities for educators, a link to the NOVA Web site, scene selections, and video descriptions for the visually impaired.

ONLINE RESOURCE

Google Scholar. Created by Anurag Acharya. Online resource. ***www.scholar.google.com***

Google Scholar is a new search engine that enables a user to search specifically for scholarly literature, including peer-reviewed papers, theses, books, preprints, abstracts, and technical reports from all broad areas of research. Google Scholar can be used to find articles from a wide variety of academic publishers, professional societies, preprint repositories, and universities, as well as scholarly articles available across the Web. Just as with Google Web Search, Google Scholar orders search results by how relevant they are to your query, so the most useful references appear at the top of the page. This relevance ranking takes into account the full text of each article as well as the article's author, the publication in which the article appeared, and how often it has been cited in scholarly literature. Google Scholar also automatically analyzes and extracts citations and presents them as separate results, even if the documents they refer to are not on line; search results may include citations of older works and seminal articles that appear only in books or other offline publications.

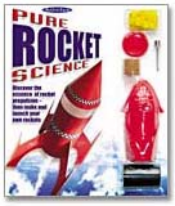
FOR KIDS!!!

Space Thrills Poster. By NASA Discovery Program, 2004. 33-inch by 25-inch poster. Grade levels K–4, free of charge. ***discovery.nasa.gov***

This new poster for K–4 students uses reading and writing activities to teach students about the solar system. Students will **Meet Our Solar System** and ponder **Solar System Mysteries**. *Teacher Tips and Resources* and *Student Activities* are included. Image and text can be downloaded from the NASA Discovery Web site, or copies of the poster can be requested by contacting the NASA Discovery Program Education and Public Outreach Department.

The Man Who Went to the Far Side of the Moon: The Story of Astronaut Michael Collins. By Bea Uusma Schyffert. Chronicle Books, 2003. 80 pp., Paperback, $14.95. ***www.chroniclebooks.com***

Do you know the story of Michael Collins, the Apollo 11 astronaut who went all the way to the Moon but never walked on its surface? Instead, he orbited the Moon 14 times, surrounded by 701 power switches and 20 pounds of checklists. Reminiscent of a scrapbook, this book chronicles what Michael Collins did, saw, and thought about in space. Through fascinating facts, quotes, checklists, original drawings, and photos taken both in space and on Earth, it also tells how the astronauts prepared for their historic journey, what they brought with them, and what they left behind. Ages 9–12.



Pure Rocket Science Action Pack. By Top That! Kids, 2004. 24-page book and toys, Paperback, $7.99. ***www.topthatpublishing.com***

Get a piece of the action with this creative and fun-filled pack that introduces the reader to the wonderful world of rocket science. This kit includes a 24-page book and blister pack containing interactive components. Step-by-step instructions and full-color photography make it easy for kids to make great models and master new skills. By following the instructions, budding rocket scientists can make and launch some incredible contraptions into the air! Ages 7 and up.

Discovery Channel School: Stargazing DVD. Presented by Discovery Channel, 2004. 26 minutes, $69.95. ***school.discovery.com***

In this galactic adventure presented by the Discovery Channel, students travel to the Moon and planets and gaze beyond our solar system. This live-action program, designed to correlate to elementary school standards, features four episodes of *TLC Elementary School*, including "The Moon: Past and Future", "Space Travel", "The Inner Planets", and "The Hubble Space Telescope". Ages 8–12.

Mars Space Sand. By Dunecraft, Inc. Half-pound bag, $5.95. ***www.dunecraft.com***

Fun, interesting, weird — just some of the words used to describe Space Sand. The soil on Mars is very similar to Space Sand in terms of properties and color. This unbelievable nontoxic sand will not get wet and can be formed into shapes under water. Remove it from the water with a teaspoon and it instantly turns to completely dry sand!

Calendar 2005

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

March

7–10 From Disks to Planets: New Observations, Models and Theories, Pasadena, California.
http://msc.caltech.edu/conferences/2005/disks05/

14–18 36th Lunar and Planetary Science Conference (LPSC), League City, Texas.
http://www.lpi.usra.edu/meetings/lpsc2005/

14–18 Near-Field Cosmology with Dwarf Elliptical Galaxies, Les Diablerets, Switzerland
http://www.mso.anu.edu.au/IAUC198/

April

3–7 Space 2005: The First International Conference and Exposition on Access, Habitation, Exploration, Business and Science in Space, Albuquerque, New Mexico.
http://www.sesinstitute.org/Papers/call.html

4–7 21st National Space Symposium, Colorado Springs, Colorado.
http://www.spacesymposium.org/

4–9 Astrophysical Fluid Dynamics, Broomfield, Colorado.
http://www.ipam.ucla.edu/programs/pcaws1/

5–8 Space Weather Week, Los Angeles, California.
http://www.sec.noaa.gov/sww/

10–14 NAI 2005 Biennial Meeting of the NASA Astrobiology Institute, Boulder, Colorado.
http://nai.arc.nasa.gov/nai2005/index.cfm

24–29 European Geosciences Union General Assembly 2005, Vienna, Austria.
http://www.copernicus.org/EGU/ga/egu05/index.htm

May

2–5 2005 May Symposium: A Decade of Extrasolar Planets Around Normal Stars, Baltimore, Maryland.
http://www.stsci.edu/institute/conference/may_symp

15–18 Halifax 2005, Halifax, Nova Scotia, Canada.
http://www.dal.ca/~hfx2005/welcome.htm

16–20 Massive Star Birth: A Crossroads of Astrophysics, Acireale, Italy.
http://www.arcetri.astro.it/~iaus227/splash.html

20–25 15th Annual Goldschmidt Conference: A Voyage of Discovery, Moscow, Idaho.
http://www.the-conference.com/2005/gold2005/index.php

22–26 15th IAA Humans in Space Symposium, Graz, Austria.
http://www.uni-graz.at/space2005/

23–27 AGU Joint Assembly, New Orleans, Louisiana.
http://www.agu.org/meetings/sm05/

29–June 2 206th Meeting of the American Astronomical Society, Minneapolis, Minnesota.
http://www.aas.org/meetings/meeting_dates.html

31–June 3 Workshop on Oxygen in Asteroids and Meteorites, Flagstaff, Arizona.
http://www.lpi.usra.edu/meetings/am2005/

June

20–24 Astrophysical Sources of High Energy Particles and Radiation, Turon, Poland.
http://www.ncac.torun.pl/~torun05/servlet/ashepr

20–24 5th International Scientific Conference on the Global Energy and Water Cycle, Orange County, California.
http://www.gewex.org/5thconf.htm

July

11–14 Workshop on the Role of Volatiles and Atmospheres on Martian Craters, Laurel, Maryland.
http://www.lpi.usra.edu/meetings/volatiles2005/

11–15 Ultra-Relativistic Jets in Astrophysics: Observations, Theory, Simulations, Banff, Alberta, Canada.
http://www.capca.ucalgary.ca/meetings/banff2005/poster.html

26–29 The 9th Asian-Pacific IAU Meeting 2005, Bali, Indonesia.
http://www.as.itb.ac.id/APRIM2005/cover.htm

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http://www.lpi.usra.edu/store/products.cfm

EDUCATIONAL PRODUCTS

Quantity	Code	Title	Price	Total
	C-SSRG-2	SPACE SCIENCE REFERENCE GUIDE, 2ND EDITION **(CD-ROM)** *FREE SHIPPING!*	$0.00	
	R-SPEC-2	ALTA REFLECTANCE SPECTROMETER **(version 2, 11 colors)** A simple classroom instrument designed to help students learn about light, color, and spectroscopy. The ALTA handheld spectrometer weighs only 9 ounces. **(scientific instrument)**	$160.00	
	B-RSPECTG	ALTA REFLECTANCE SPECTROMETER CLASSROOM LESSONS **(book)**	$25.00	
	C-RSPECTG	ALTA REFLECTANCE SPECTROMETER CLASSROOM LESSONS **(CD-ROM)**	$5.00	
	C-CLA	CONSOLIDATED LUNAR ATLAS **(CD-ROM)**	$10.00	
	C-LOPA	DIGITAL LUNAR ORBITER PHOTOGRAPHIC ATLAS **(DVD)**	$10.00	
	C-LMC	LUNAR MAP CATALOG **(CD-ROM)**	$10.00	
	LSB	LUNAR SOURCEBOOK **(CD-ROM)**	$20.00	

OTHER PUBLICATIONS

AVAILABLE FOR THE COST OF SHIPPING AND HANDLING

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	CB-1084	FORUM ON INNOVATIVE APPROACHES TO OUTER PLANETARY EXPLORATION 2001–2002 **(book)**	$0.00	
	CB-1095	CONFERENCE ON THE GEOPHYSICAL DETECTION OF SUBSURFACE WATER ON MARS **(book)**	$0.00	
	CB-1106	FOURTH ANNUAL HEDS-UP FORUM **(book)**	$0.00	
	CB-1129	SOLAR SYSTEM REMOTE SENSING **(book)**	$0.00	
	CB-1134	UNMIXING THE SNCs: CHEMICAL, ISOTOPIC, AND PETROLOGIC COMPONENTS OF THE MARTIAN METEORITES **(book)**	$0.00	
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	CB-1182	WORKSHOP ON COMETARY DUST IN ASTROPYSICS **(book)**	$0.00	
	CB-1195	WORKSHOP ON EUROPA'S ICY SHELL: PAST, PRESENT, AND FUTURE **(book)**	$0.00	
	CB-1203	OXYGEN IN THE TERRESTRIAL PLANETS **(book)**	$0.00	
	C-33	LPSC XXXIII ABSTRACTS **(CD-ROM)**	$0.00	
	C-1184	THIRD INTERNATIONAL CONFERENCE ON MARS POLAR SCIENCE AND EXPLORATION **(CD-ROM)**	$0.00	
	C-34	LPSC XXXIV ABSTRACTS **(CD-ROM)**	$0.00	
	C-35	LPSC XXXV ABSTRACTS **(CD-ROM)**	$0.00	
	C-1088	ELEVENTH ANNUAL V. M. GOLDSCHMIDT CONFERENCE **(CD-ROM)**	$0.00	
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