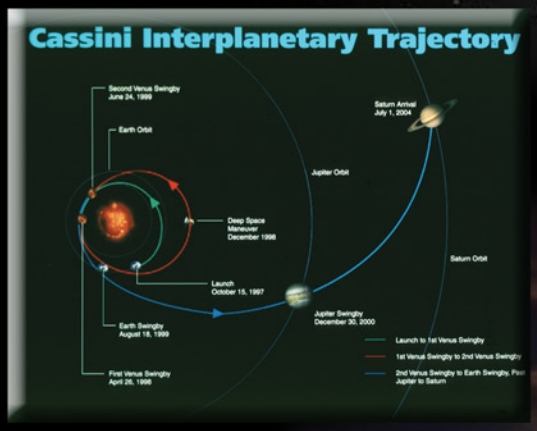
Titan — International Moon of Mystery



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TITAN — INTERNATIONAL MOON OF MYSTERY

— Ralph Lorenz, University of Arizona

While the arrival of the Mars rovers has made 2004 a landmark year for planetary exploration, another mission has been quietly closing in on its target, one that may rival Mars in both scientific importance and public appeal. The Cassini mission, a joint endeavor between NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI), is about to arrive in the saturnian system, last visited fleetingly by Voyager 2 in 1981. This monster project involves a large Saturn orbiter spacecraft and a European-built probe named Huygens, which will descend to the surface of Saturn's largest moon, Titan, and promises a bonanza of scientific discoveries. While Saturn, adorned by beautiful rings and attended by a diverse zoo of moons, offers as much interest as the jovian system, it is Titan that is set to take center stage.

TITAN: AN ICY GIANT WITH AN EXOTIC FAMILIARITY

Titan is the second-largest satellite in the solar system (Jupiter's Ganymede is slightly larger). Its radius is 2575 kilometers, between the sizes of the planets Mars and Mercury. What makes Titan particularly interesting is that it has a thick atmosphere, made mostly of molecular nitrogen, just like our own. Titan's atmosphere is denser than our own — by a factor of 4 at sea level (a term that may apply literally!).

Understanding how Titan acquired its atmosphere, and how that atmosphere evolved over time, is an important task. Titan's gravity is 1.35 m s^{-2}, about one-seventh that of Earth's (very similar to our Moon). But being so far from the Sun, Titan is very cold; its surface temperature is 94 K (–179°C), and in this deep cold, the gas molecules are not energetic enough to escape even Titan's weak gravity.

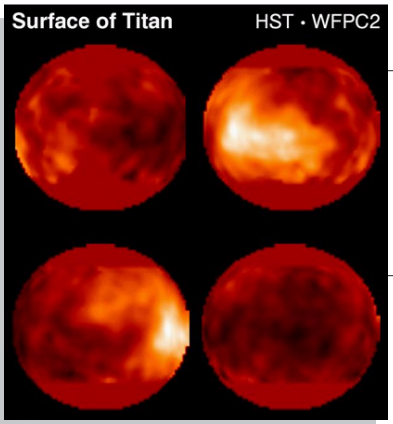
This Voyager 2 photograph of Titan, taken August 23, 1981, from a range of 2.3 million kilometers (1.4 million miles), shows some detail in the cloud systems on this saturnian moon. The southern hemisphere appears lighter in contrast, a well-defined band is seen near the equator, and a dark collar is evident at the north pole. All these bands are associated with cloud circulation in Titan's atmosphere. The extended haze, composed of submicrometer-sized particles, is seen clearly around the satellite's limb. This image was composed from blue, green, and violet frames. — Image courtesy of JPL's Planetary Photojournal.

Titan's atmosphere differs from the Earth's in that it has no oxygen. Instead, the second major constituent in Titan's atmosphere is methane, a principal component of natural gas on Earth. But Titan is so cold that methane behaves like water on Earth — it can exist in liquid form and, at high altitude, as an ice. Observations from Earth have already shown that methane clouds form and dissipate in a few hours or days, just like thunderclouds on Earth.

Titan would be even colder than it is were it not for the fact that methane is a strong greenhouse gas that helps the surface retain its heat. However, the methane is continuously destroyed by ultraviolet light from the Sun, and this process creates ethane, which may accumulate as a liquid on Titan's surface, and a rich organic smog that makes Titan's atmosphere nearly opaque to visible light. The fact that we see short-lived methane in the atmosphere today suggests that it may be resupplied to the atmosphere, perhaps from a large reservoir on the surface, like seas of methane and ethane. Last year, radar observations using the giant Arecibo radio telescope showed that Titan indeed seems to have such seas.

Titan, which otherwise might be an icy satellite just like any other (Europa, Ganymede, etc.), is much like an Earth in deep freeze. While much of the chemistry is different — methane instead of water, ice instead of rock, haze instead of ozone — many of the same processes are in action. Clouds, rain, and hail, as well as waves and tides in seas, will be at work beneath the haze. Perhaps there are also geysers, whirlwinds, or volcanos. The exotic circumstances on Titan will open up a new window into understanding these processes, not only in this bizarre new setting, but also on Earth.

We have been able to observe year-to-year changes in Titan's atmosphere. Titan's equator is tilted in a manner very similar to Earth's, so it has seasons. Images from the Hubble Space Telescope show that some of the haze blows from one hemisphere to the other, driven by solar-powered winds. The haze is progressively more transparent toward red and near-infrared light, and Hubble and many groundbased telescopes have been able to make crude maps of Titan. The best of these maps are comparable with the detail with which we can see the moon with the naked eye. There are some dark spots that might be tar pits, formed as the organic haze accumulates on the surface, or lakes of methane and ethane. The leading face of Titan (Titan is tidally locked, and so keeps the same face pointing at Saturn) is occupied by a large bright region the size of Australia, and may have a more icy composition. Titan is a varied, dynamic place that begs a closer look.



Four global projections of the Hubble Space Telescope Titan data, separated in longitude by 90°. Upper left: Hemisphere facing Saturn. Upper right: Leading hemisphere (brightest region). Lower left: The hemisphere that never faces Saturn. Lower right: Trailing hemisphere. Note that these assignments assume a synchronous rotation. The data obtained by the imaging team strongly support this assumption — a longer time baseline is needed for proof. The surface near the poles is never visible to an observer in Titan's equatorial plane because of the large optical path.
— Image courtesy of JPL's Planetary Photojournal.

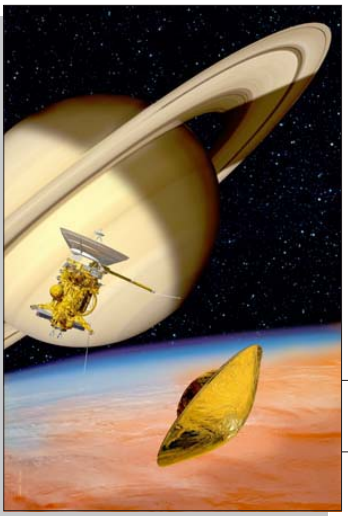
CASSINI: THE EARLY MISSION

Cassini is still millions of kilometers away from the saturnian system, but its cameras are already able to image targets with higher resolution than is possible from Earth, even using the Hubble Space Telescope. These approach images will just get better and better as the weeks pass. One approach highlight is a close flyby of Phoebe (radius 110 kilometers), which was until recently thought to be Saturn's outermost satellite. This satellite is in a retrograde orbit, suggesting that perhaps it is a captured asteroid or Kuiper belt object. On June 11, Cassini will sweep by, only 1000 kilometers away, 2000 times closer than the Voyager encounter!

On July 1, Cassini brakes into orbit around Saturn, making its closest approach to Saturn and the rings as it does so. This will be an awesome opportunity to study Saturn's magnetic field and rings up close, perhaps "sniffing" them directly with its dust analyzer and plasma instruments.

This is an artist's concept of Cassini during the Saturn Orbit Insertion (SOI) maneuver, just after the main engine has begun firing. The spacecraft is moving out of the plane of the page and to the right (firing to reduce its spacecraft velocity with respect to Saturn) and has just crossed the ring plane. The SOI maneuver, which is approximately 90 minutes long, will allow Cassini to be captured by Saturn's gravity into a five-month orbit. Cassini's close proximity to the planet after the maneuver offers a unique opportunity to observe Saturn and its rings at extremely high resolution.
— Image courtesy of JPL's Planetary Photojournal.

Cassini's first orbit is a long, lazy one. On the way out, on July 3, there is an excellent viewing opportunity for Titan's south pole, from 300,000 kilometers away. This will give us a chance to verify the state of Titan's atmosphere in preparation for the delivery of the Huygens probe.



An artist's impression of Cassini-Huygens at Saturn.
— Illustration by David Ducros, courtesy of ESA.

On the way back toward Saturn, Cassini will make its first close flyby of Titan, at an altitude of 1200 kilometers. This event, on October 25 of this year, will put most of Cassini's arsenal of instruments through their paces. We will learn how well the optical and near-infrared instruments can see through Titan's haze, and get our first high-resolution look at Titan's landscape with Cassini's RADAR instrument, which will map parts of the surface with a resolution of 500 meters.

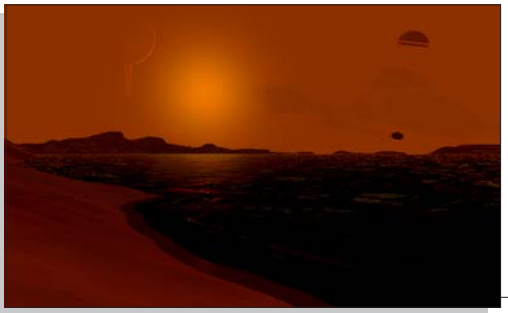
In the following months there will be another Titan encounter, as well as close looks at Enceladus and Iapetus. Saturn, along with its rings and magnetosphere, will come under close scrutiny in a bonanza of data of many gigabits per week.

ENCOUNTER WITH TITAN

In many ways the highlight of Cassini's four-year mission will be only a three-hour event, set to occur on January 14, 2005. Having been released on December 25, the Huygens probe will slam into the top of Titan's atmosphere at a speed of 6 kilometers per second.

After decelerating in Titan's thick cushion of an atmosphere, Huygens will jettison its heat shield at an altitude of around 160 kilometers and deploy a parachute and its instruments. It will take between two and two-and-a-half hours to reach the surface. The probe will observe light scattering in the atmosphere and will suck in haze particles and gas to measure their chemical composition. Other instruments will measure the temperature profile of the atmosphere and the winds. All eyes, however, will be on the University of Arizona's Descent Imager and Spectral Radiometer, which will take panoramic pictures as the probe slowly spins around under its parachute.

When the radiometer reaches the surface, no one knows what will happen. It hits the deck at 5 meters per second, the speed of a calculator dropped from a desk. The probe could not be designed to guarantee survival — there can be no guarantees in a completely unknown environment — but at this modest speed, it may survive impact with a soft surface like snow. On the other hand, an icy rock or some other pathological surface could end the mission instantly.



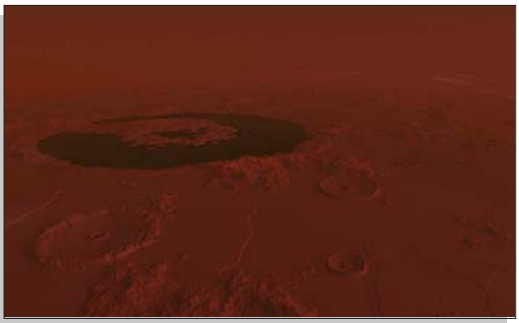
Perhaps the most likely surface is a wet one. Huygens may splash down into a lake of hydrocarbons. This may be, mechanically, like gasoline, or perhaps like tar. But a splashdown should be survivable, and Huygens may be able to measure the height of any waves as it bobs up and down, determine the composition of the liquid, and perhaps measure its depth, using a small sonar that is part of the British-led Surface Science Package.

In this rendering, the Huygens probe (shape model derived from various sources) is about to splash down on the Saturn side of Titan, rather than on the side we will actually visit. (In fact, Saturn's proximity to the horizon shows we are close to ±80° longitude: The orientation of the rings as near-vertical shows we are close to the equator. The Sun's position relative to Saturn shows we are close to summer solstice (although from this image you can't tell north from south). Titan's atmosphere really should be this transparent, at least at some wavelengths accessible to cameras, if not to the naked eye.
— Artwork by Mark Robertson-Tessi and Ralph Lorenz.

After a few tens of minutes at most, the mission will end. The probe's batteries will run down, and Cassini, which relays its data down to Earth, passes out of sight. When Cassini next flies past Titan several weeks later, Huygens will be cold and dead.

However, another 40 flybys of Titan will take place in the following two-and-a-half years of the nominal tour. These flybys will perform radar mapping; measure the field and plasma interactions with the magnetosphere; observe the Sun or stars through Titan's atmosphere, profiling its chemical and haze structure; make quiet precision tracking passes to measure Titan's gravitational field and thus probe its interior, measuring the size of its core; and, of course, obtaine lots and lots of pictures. Scientists have so many exciting investigations to perform with Cassini's formidable arsenal of instruments that they hope Cassini may perform well enough to study Titan beyond the end of the nominal tour, which ends in June 2008.

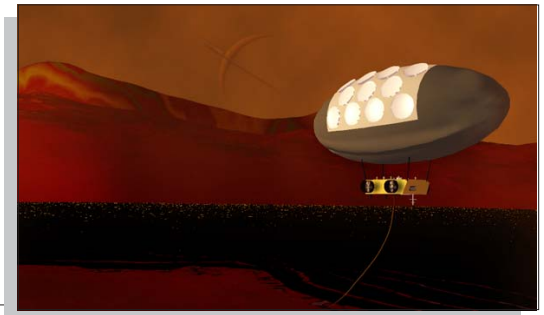
A scientifically inspired artistic rendering of Titan's hypothesized landscape. Seen from a viewpoint 50 kilometers up, the planetary curvature of Titan (radius 2575 kilometers) is evident. A 60-kilometer impact crater, to the left, has an updomed floor and a central pit, as seen in craters of this size on the icy satellite Ganymede; on Titan, however, the crater has partially filled with black hydrocarbon liquids — methane and ethane. A few other craters and tectonic landforms litter the landscape, which is only weakly modified by erosion. Distant clouds hover at around 20 kilometers altitude.
— Artwork by Mark Robertson-Tessi and Ralph Lorenz.



AFTER CASSINI: THE SEARCH FOR LIFE'S ORIGINS

It takes a very long time to design and build spacecraft and instruments for the outer solar system, and another long time to get them there. Cassini was proposed in the early 1980s, soon after the Voyager encounter. Thus, for the next mission to follow Cassini, it is already time to begin devising mission concepts.

There are many possible options, and the first data from Cassini and Huygens will be important in formulating the precise objectives for a successor. It seems certain, however, that scientific attention will focus on the near surface. Not only is Titan's meteorology and oceanography likely to merit detailed study, but the surface and near-subsurface is of particular interest in the study of the origin of life. Deep beneath Titan's icy crust is expected to lie a layer of liquid water, just like on Europa. Titan's water layer may be spiked with ammonia, acting as an antifreeze, and it may be buried deeper under the ice, but the rich abundance of organic material on Titan makes it a more attractive astrobiological target than the white sterility of Europa.



An autonomous airship exploits Titan's thick atmosphere and low gravity to explore the near-surface environment. The airship communicates directly with Earth by means of a large electronically steered phased-array antenna. Here it uses thruster fans to hold its position in the gentle breeze that is whipping up waves in an ethane lake. Having profiled the depth of the lake with a ground-penetrating radar, the airship is acquiring surface material with a tethered sample acquisition device to analyze it for prebiotic compounds. — Artwork by Mark Robertson-Tessi and Ralph Lorenz.

Even if the deep interior has long been isolated from the surface, liquid water will have made occasional appearances on Titan — formed as shock-melted ice in large crater-forming impacts. The melt pools formed in craters may take tens of thousands of years to freeze solid, forming an ever-concentrating organic soup as they do so. Probing the chemical composition of these ices and looking for organized chemistry will perhaps be the main objective of a future mission. Laboratory experiments show that when material (called "tholin") resembling Titan's haze is added to water, it quickly forms amino acids and other building blocks of biological molecules. But no one can do an experiment lasting thousands of years to see how these blocks assemble themselves. We have to go where the experiment has been done for us and the results conveniently frozen for our collection.

Titan's thick atmosphere and low gravity make it is an attractive place for flying machines. A balloon or airship can be quite compact, and a helicopter could fly using 38 times less power than it would need on Earth. The vehicle could either land to sample the surface chemistry, or perhaps drop an expendable mini-probe or lower it on a tether. An airborne platform offers the ability to rove around on planetary scales, rather than on the football-field scales that the Mars rovers can presently manage, and will give us a magnificent vista on this amazing new world.

Suggested Reading Materials . . .

For more information about Saturn and Titan, visit these Web sites:

http://saturn.jpl.nasa.gov/
http://sci.esa.int/
http://www.lpl.arizona.edu/~rlorenz

You can also read the book *Lifting Titan's Veil* by R. Lorenz and J. Mitton, Cambridge University Press, 2002.

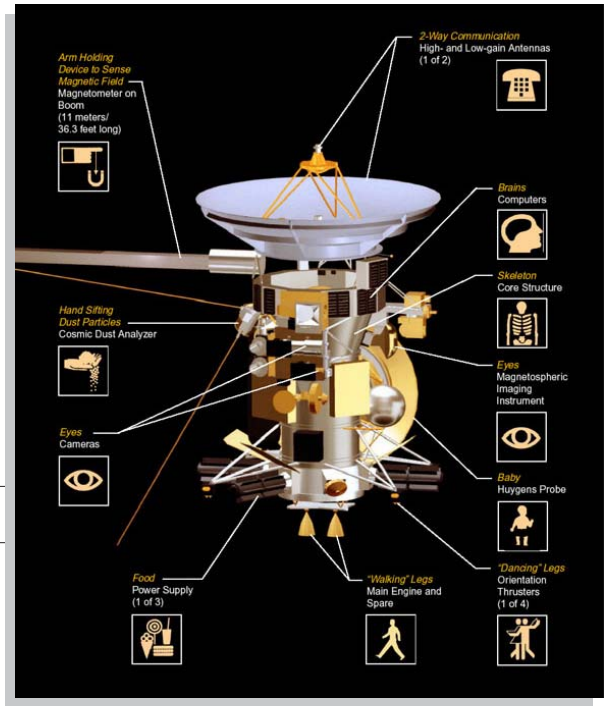


Diagram of the Cassini spacecraft.

Meeting Highlights

35th Lunar and Planetary Science Conference

The 35th Lunar and Planetary Science Conference (LPSC) marked an incredible record-breaking year, with 1317 participants from 24 countries attending the conference held at the South Shore Harbour Resort and Conference Center in League City, Texas, on March 15–19, 2004. This year's attendance statistics reflect a continuing excitement about the future of planetary science.

35th LPSC at a Glance

Total number of attendees: 1317

Student attendees: 359

Abstracts received: 1189
Abstracts accepted: 1161

Oral presentations: 476
Poster presentations: 588

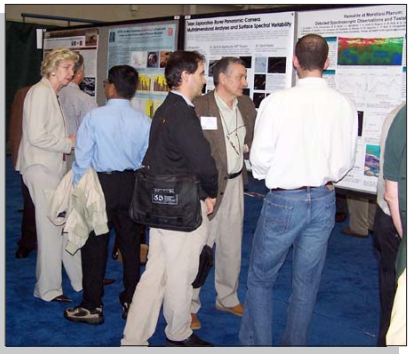
Attendance from Non-U.S. Countries:

Australia: 8	India: 1
Austria: 2	Italy: 9
Belgium: 3	Japan: 66
Brazil: 2	Netherlands: 11
Canada: 18	Norway: 1
Croatia: 1	Portugal: 3
Czech Republic: 2	Russia: 5
Denmark: 1	South Africa: 3
Finland: 2	Spain: 8
France: 35	Switzerland: 8
Germany: 37	United Kingdom: 42
Hungary: 4	Vatican City State: 1

Total non-U.S. attendees: 273

LPSC has long been recognized among the international science community as the most important planetary conference in the world, and this year's meeting substantiated the merit of that reputation. Hundreds of planetary scientists attended both oral and poster sessions focusing on such diverse topics as meteorites; the Moon, Mars, and Venus; impacts; outer planets and satellites; comets, asteroids, and other small bodies; interplanetary dust particles and presolar grains; origins of planetary systems; planetary formation and early evolution; and astrobiology. Sunday night's registration and reception were held at the Center for Advanced Space Studies, which houses the Lunar and Planetary Institute. Sunday night's events again featured an open house for the display of education and public outreach activities and programs.

Highlights of the conference program, established by the program committee under the guidance of co-chairs Dr. Stephen Mackwell (Lunar and Planetary Institute) and Dr. Eileen Stansbery (NASA Johnson Space Center), included oral and poster sessions on results from the Stardust mission as well as special sessions on oxygen in the solar system, Mars climate change, and results from the recent successful Mars Exploration Rovers and Mars Express missions. The oral sessions on early results from Stardust and the Mars missions in particular were exceedingly popular, with lecture halls filled to capacity well in advance of the first talk. During the Monday afternoon plenary session, the Masursky Lecture was presented by Professor S. Ross Taylor of the Australian National University. In his talk, entitled "Planetary Science: A New Discipline?," Taylor noted that the study of planets is difficult as, unlike stars, planets are individuals bodies that were formed by stochastic processes, and therefore cannot be placed into pigeonholes. Even planets as close in mass and density as Earth and Venus have turned out to be more like Dr. Jekyll and Mr. Hyde, and it is important to understand how this happened as the search for extrasolar Earth-like planets continues. Later that evening, a student/scientist reception provided students with an opportunity to meet and interact with Taylor, as well as other scientists.



A record number of posters prompted many lively discussions among participants.

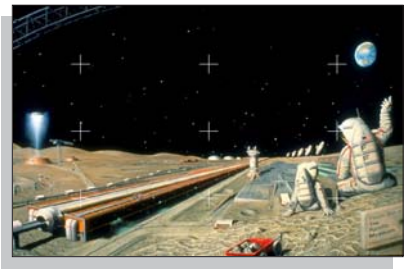
Professor Ross Taylor presented the Masursky Lecture.

On Monday evening NASA Headquarters staff briefed the community on the status of the Solar System Exploration Division, as well as provided important insight into the new programs developing in response to the President's new initiative for Exploration of the Solar System. This briefing was followed by a discussion forum with members of the President's Commission for Implementation of U.S. Space Policy (Moon, Mars, and Beyond), where members of the academic community were given the opportunity to provide suggestions and recommendations for the Commission.

Mr. Orlando Figueroa opened the NASA Headquarters briefing.

Plans are already underway for the 36th LPSC, which will again be held at South Shore Harbour Resort and Conference Center. The dates for next year's conference will be March 14–18, 2005, with the first announcement scheduled for release later this summer. *Mark your calendars!*

WORKSHOP ON LUNAR KNOWLEDGE REQUIREMENTS



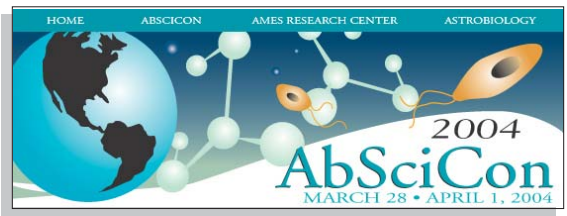
In response to the President's new NASA initiative for Exploration of the Solar System, announced in January, the Workshop on Lunar Knowledge Requirements for Human Exploration was held at the Lunar and Planetary Institute in Houston on March 1–2, 2004. Convened by Dr. G. Jeffrey Taylor of the University of Hawai'i and Dr. Stephen Mackwell of the Lunar and Planetary Institute, 53 attendees representing universities, NASA centers, and NASA Headquarters discussed current knowledge of the Moon and data needs for future robotic and manned missions to the Moon. Working groups focused on mission operations, assessment of resources, and resource and regolith processing. The meeting concluded with a discussion of a possible set of measurements that could be attained with a resource- and schedule-constrained Lunar Reconnaissance Orbiter Mission planned for launch before the end of the 2008 calendar year. All documents associated with the meeting, including copies of older reports dealing with lunar resource issues and a final summary document, are available on the meeting site at *http://www.lpi.usra.edu/lunar_return*.

WORKSHOP ON EUROPA'S ICY SHELL: PAST, PRESENT, AND FUTURE

Europa, a Moon-sized ice-covered satellite of Jupiter, is second only to Mars in its astrobiological potential. Beneath the icy surface, an ocean up to 150 kilometers deep is thought to exist, providing a potential habitat for life, and a tempting target for future space missions. The Galileo mission to the jovian system recently ended, but there are already long-range plans to send much more capable spacecraft, such as the proposed Jupiter Icy Moons Orbiter (JIMO), to take a closer look at Europa and her siblings Ganymede and Callisto sometime in the next two decades. Europa's outer icy shell is the only interface between this putative ocean and the surface, but many aspects of this shell are presently poorly understood, particularly its composition, thickness, deformational history, and mechanical properties.

To discuss the ice shell and our current understanding of it, 78 scientists from the terrestrial and planetary science communities in the U.S. and Europe gathered for a 2.5-day workshop hosted by the Lunar and Planetary Institute in Houston on February 6–8, 2004. A key goal of the workshop was to bring researchers from disparate disciplines together to discuss the importance and limitations of available data on Europa with a post-Galileo perspective. The workshop featured two days of reviews and contributed talks on the composition, physical properties, stratigraphy, tectonics and future exploration of the ice shell and underlying ocean. The final morning included an extended discussion period, moderated by a panel of noted experts, highlighting outstanding questions and areas requiring future research. While the meeting did not resolve the properties of Europa's ice shell (nor was it expected to), what it did provide was a much better understanding of where the greatest uncertainties lie, and what the most fruitful avenues of scientific investigations are likely to be. As the JIMO program ramps up, and the results from Cassini start to arrive, icy satellites and Europa in particular will continue to be a focus of attention for the planetary and terrestrial ice community. Additional information about the workshop (including meeting announcements, the agenda, and abstracts accepted for presentation) is available at *http://www.lpi.usra.edu/meetings/europa2004*.

ASTROBIOLOGY SCIENCE CONFERENCE



AbSciCon 2004, the Astrobiology Science Conference, was held at NASA Ames Research Center in Moffett Field, California, from March 28 through April 1, 2004. The conference, sponsored by NASA, is held every second year and alternates with the NASA Astrobiology Annual General Meeting. This year's conference covered a broader range of topics than in the past, with discussion involving topics as varied as astrobiology and the press, astrobiology in museums, ethics and exploration, and religion, as well as the more typical sessions dealing with the origins of life and life on other planets. In addition to informative oral sessions providing in-depth coverage of such topics as Earth history and hypersaline environments, the conference also included a poster session with a number of high-quality poster presentations on such diverse topics as Europa and the abiotic Earth. For more information about past and future AbSciCon meetings, visit the Web site at *http://abscicon.arc.nasa.gov/*.

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.

Learning from the Frontier: Getting Planetary Data in the Hands of Educators

Approximately 60 researchers and educators participated in the March 13 Workshop on Learning from the Frontier, held at the Lunar and Planetary Institute in Houston, Texas. The workshop was co-hosted by the South Central Organization of Researchers and Educators (SCORE) and the Solar System Exploration Education Forum, both part of NASA's Office of Space Science's Support Network. The workshop goals were to initiate a dialog among those interested in identifying paths for bringing planetary data to educators; to better understand key challenges facing educators who are working with planetary data and issues with gaining access to data; to identify common aspects of the success of programs and products developed to make data accessible in educational venues; and finally, to identify the remaining challenges and make recommendations for how the community should move forward to bring these data into the classroom. Participants included researchers, formal and informal education specialists, classroom educators, data archivists, and educational product developers.

Dr. Phil Sakimoto, Acting Director of Space Science Education and Public Outreach in NASA's Office of Space Science, set the stage by reminding participants that NASA missions are not complete until the discoveries and science have been returned to the American people and to students in particular. He urged workshop participants to work to get the wealth of existing solar system data beyond the scientists and into the hands of educators.

Dr. Phil Sakimoto addressed workshop participants.

Presentations by researchers and educational specialists encompassed the facilitation of accessing data, effective use of data in the classroom, availability of data for use by the educational community, and paths for accessing and using mission data. Panel discussions explored the experiences of researchers, educators, and product developers in creating and implementing programs and products and the challenges remaining for integrating planetary data into educational environments. Discussion among all participants resulted in the following recommendations for the development and implementation of successful programs:

- Materials are often developed for students and educators without understanding the needs of these groups. The intended audience should be invited to play an active role in the design and development process.
- The perfect educational product cannot be used without the audience knowing how to do so. Program and product implementation should incorporate adequate training and support for intended users.
- Accessing data remains challenging, even to researchers. Students and educators need to be able to access and manipulate data with ease. This may require filtering of raw data and new user interfaces.
- Educators often do not have the time to search for data, develop a comprehensive understanding of the data, place the data in a context that is appropriate and meaningful for their students, and incorporate the data into the curriculum. Authentic data should be presented within the context of a lesson or an exploration that is appropriate for the age level, with ties to standards, assessments, and connections to other disciplines such as language arts and math.
- Data need to be accessible not solely in the context of a mission, but within a broader context of important scientific questions and understanding.
- The potential community involved in the educational use of planetary data is large; resources such as master teachers, museums, pre-service faculty, minority organizations, amateur astronomers, and others should be involved and leveraged.

The complete list of recommendations, presentations, and participants will be posted at the SCORE Web site (*http://www.lpi.usra.edu/score*) in early summer. Interested individuals can join a list-serv, access resources, learn more about programs that community members consider successful models of planetary data use, and find out about upcoming opportunities to be involved in future workshops.

Space Day 2004

The eighth annual Space Day celebration will take place on May 6, 2004. The Space Day educational initiative, founded by Lockheed Martin, focuses on sharing the achievements, benefits, and opportunities of space exploration with students, educators, and communities. Events include a Design Challenge, through which students design, develop, and submit solutions to challenges faced by the space science community. The 2004 Design Challenge

topics include developing a multipurpose tool for exploring and/or surviving in our solar system and designing a manned or remotely operated vehicle to explore a region of the solar system. A downloadable Space Day Launch Kit offers tips on planning events, educational materials, and press and promotional information. To find out how to host a Space Day event, or find out about Space Day activities in your region, visit the Space Day Web site at *http://www.spaceday.org/index.html*.

NEW VIEWS

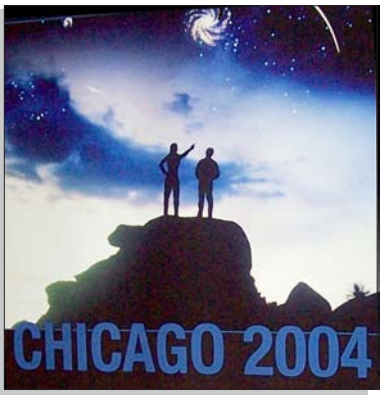
On May 1, 2004, from 3:00 to 4:00 p.m. (U.S. Eastern Daylight Time), Passport to Knowledge will present "New Views" live from the St. Louis Science Center in St. Louis, Missouri. Hosted by Bill Nye with NASA scientists and engineers, New Views will share the scientific results from NASA's Mars Exploration Rover mission. What do the first findings imply for the possibility of past or present life on Mars? Viewers can send questions via e-mail, and receive instant answers from NASA researchers and Mars experts. "New Views" will be aired by participating PBS stations (check local listings). For more information, go to the Passport to Knowledge Mars Web site at *http://passporttoknowledge.com/mars/*.

VENUS TRANSITS THE SUN

On June 8, 2004, a celestial event of historical scientific importance will occur when Earth viewers can watch the silhouette of the planet Venus cross the face of the Sun. This event — the transit of Venus — last occurred in 1882. Information and materials are available to prepare for event viewing through the Sun-Earth Connection (SEC) Education Forum at the Venus Transit Web site (*http://sunearth.gsfc.nasa.gov/sunearthday/*). The Exploratorium, in collaboration with the SEC Education Forum, will host a live Webcast of the event from the National Observatory of Greece for a clear view of this rare occurrence.

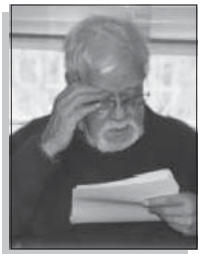
REMINDER: CHICAGO 2004

NASA's Office of Space Science (OSS) is sponsoring a workshop on June 28–29, 2004, to foster broader participation in NASA's space science missions and research programs. The workshop is designed for established space science researchers who recognize the importance of broadening the diversity of participants in NASA's space science missions and research programs, minority or minority university scientists who are interested in space science, and individuals in a position to positively influence the membership of future space science research teams. Two days of briefings and discussions will focus on future OSS missions and research program plans and opportunities, designing successful teams and proposals, and developing plans and solicitations for future OSS missions and research programs. A primary emphasis of the workshop is providing time for developing partnerships. Preregistration closes June 18. More information can be found at the Web site at *http://analyzer.depaul.edu/Chicago2004/*.



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 NASA's Education Web site at http://spacescience.nasa.gov/education/index.htm.

In Memoriam



Robert M. Walker passed away on February 11, 2004, at the age of 75, after a year-long fight with stomach cancer. Walker was one of the great visionaries in the space sciences, and his imagination, sense of scientific rigor, and passion for the microscopic world and its use as a window to the cosmos has been imprinted on several generations of physicists, space scientists, and cosmochemists. His scientific interests included fundamental contributions to particle physics, nuclear physics (the discovery of nuclear particle tracks and the invention of fission track dating), and cosmic-ray physics. His recognition of the potential importance of the ion microprobe for making isotopic measurements on microscopic samples directly led to numerous spectacular results, including the identification and characterization of stellar condensates in meteorites and their use in constraining models of stellar nucleosynthesis. His visionary emphasis on applying multiple microanalytical techniques to the same small sample led to discoveries ranging from the identification of deuterium anomalies in interplanetary dust particles to the analysis of circumstellar oxide grains from oxygen-rich red giants. Walker was an internationally recognized scientist, receiving numerous awards and recognitions, including the E. O. Lawrence Memorial Award of the U.S. Atomic Energy Commission, the J. Lawrence Smith Medal of the National Academy of Sciences, and the Leonard Medal of the Meteoritical Society. Yet Walker he was always primarily concerned with the pursuit of science for its own sake, rather than for his own glory. He freely imparted his knowledge and skill to numerous students and postdocs, many of whom have gone on to outstanding careers, and was a tireless spokesperson and lobbyist for science.

William H. Pickering, a central figure in the U.S. space race and former director of NASA's Jet Propulsion Laboratory from 1954 to 1976, has died. Pickering — known affectionately as "Mr. JPL" and an original "Rocket Man," and one of few public figures to appear twice on the cover of *Time* magazine — passed away March 15 of pneumonia at his home in California. He was 93. In 1954, Pickering was named director of JPL. Following the first Soviet Sputnik launch, JPL and the Army Ballistic Missile Agency were given the assignment to place the first U.S. satellite in orbit. Pickering directed the JPL effort, which provided the satellite, telecommunications, and upper rocket stages that lofted Explorer 1 into orbit on January 31, 1958. It was considered one of Pickering's greatest achievements and laid the groundwork for future robotic exploration of the Moon and planets. Following the success of Explorer 1, Pickering was instrumental in leading a new era of robotic space exploration, including the first missions to the Moon and the planets.

Joseph W. Chamberlain, organizer and first chair of the Division of Planetary Sciences of the American Astronomical Society, died peacefully at age 75 on April 13, 2004. He was the author of two influential books, *Theory of the Aurora and Airglow* and *Theory of Planetary Atmospheres*, both of which have been reprinted. He organized a strong planetary group at the Kitt Peak National Observatory in the 1960s; members of this group played important roles in the Mariner 10, Pioneer Venus, Viking, Voyager, and Galileo missions. He spent two years as Director of the Lunar Science Institute (now the Lunar and Planetary Institute) and then joined the faculty of Rice University, retiring to Tucson in 1990. His most influential planetary work was in exospheric structure and atmospheric escape, solar wind theory, and analysis of spectral-line formation in cloudy atmospheres.

The *Lunar and Planetary Information Bulletin* is published by the Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.

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Production Editor: Renée Dotson
Graphic Design: Leanne Woolley

The *Bulletin* welcomes articles dealing with issues related to planetary science and exploration. The copy deadline for the next issue is **July 2, 2004**. 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*.

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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)

Save the Saturn V

Once a valiant workhorse, the *Saturn V* has become an awe-inspiring symbol of American technological achievement. Of a design and performance unparalleled, the rocket for the first time literally transported humankind to another world.

Three genuine *Saturn V* rockets remain, but only the one currently on loan and displayed outdoors at the entrance to the NASA Johnson Space Center is made up of actual flight-certified stages. Its parts created as the means for our astronauts to escape Earth and explore space, it never realized its destiny. The rocket now lies anchored to the soil.

Its Earth-bound retirement has placed the precious *Saturn V* at risk of destruction, a victim of environmental attack and scarce resources. However, a strong preservation program — linked to dedicated industry and community partners — is poised to help ensure this national treasure is preserved and returned to a condition worthy of its heritage. Hopefully, once stabilized, repaired, and returned to its original appearance, the *Saturn V* once again will shine as a testament to human achievement and daring.

What is needed? Additional matching funds for a $1.25 M grant from the prestigious Save America's Treasures Program. With over $700,000 of required funds already on hand and sufficient to begin the preservation effort this year, the Program is committed to stabilizing the rocket, determining the best techniques for preserving it, and building a temporary facility to protect the rocket from further environmental decay. But completing the repair, preservation, and return of the artifact to its original appearance will require additional support from partners who value this national treasure.

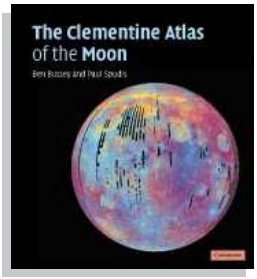
The generosity of many has put the Program's goals within grasp. At this time, additional individual, organizational, and corporate partners are needed to help provide the remaining $540,000 in matching funds that are required to complete the job.

It is anticipated that nearly a million visitors will visit the *Saturn V* annually in its new home. This is an extraordinary opportunity to support both the historic aerospace history as well as a national treasure. For more information on what you can do to help, please visit the Smithsonian Web site at *http://www.nasm.si.edu/getinvolved/giving/saturnv/*.

New and Noteworthy

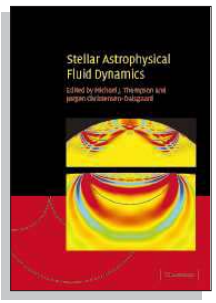
These products are available from booksellers or the publisher listed.
Please note that the LPI does not offer these products through its Order Department.

Books



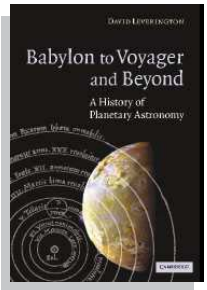
The Clementine Atlas of the Moon. By Ben Bussey and Paul Spudis. Cambridge University Press, 2004. 376 pp., Hardcover, $80.00. *www.cup.org*

The highly successful Clementine mission to the Moon in 1994 gave scientists their first global look at the Moon, and both the nearside and farside were mapped. This atlas is based on the data collected by the Clementine mission. It covers the entire Moon in 144 Lunar Aeronautical Charts (LACs), and represents the most complete lunar nomenclature database in existence, listing virtually all named craters and other features. This is the first atlas to show the entire lunar surface in uniform scale and format. A section of color plates shows lunar composition and physical properties.



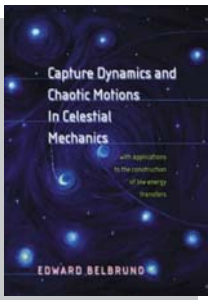
Stellar Astrophysical Fluid Dynamics. Edited by Michael J. Thompson, Jørgen Christensen-Dalsgaard. Cambridge University Press, 2003. 428 pp., Hardcover, $90.00. *www.cup.org*

This comprehensive overview of stellar astrophysical fluid dynamics includes properties of pulsating stars; helioseismology; convection and mixing in stellar interiors; and dynamics of stellar rotation, planet formation, and the generation of stellar and planetary magnetic fields. Each chapter is written by a leading expert in the field and extensive references to technical literature are made.



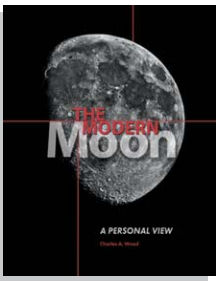
Babylon to Voyager and Beyond: A History of Planetary Astronomy. By David Leverington. Cambridge University Press, 2003. 568 pp., Hardcover, $95.00. *www.cup.org*

This book describes the fascinating story of planetary research from the time of the Babylonians and ancient Greeks to the modern age of space exploration. David Leverington outlines the key astronomical discoveries in their historical context, covering not only the successes but also many of the failures. *Babylon to Voyager and Beyond* is written to be accessible to both amateur and professional astronomers and those interested in the history of science. Extensively illustrated, the book concludes with a description of the extensive planetary discoveries made by spacecraft, and the discoveries of planets around other stars.



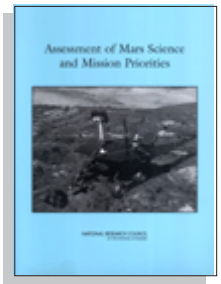
Capture Dynamics and Chaotic Motions in Celestial Mechanics: With Applications to the Construction of Low Energy Transfers. By Edward Belbruno. Princeton University Press, 2004. 224 pp., Hardcover, $49.95. *pup.pupress.princeton.edu*

This book describes a new approach to determining low-energy routes for spacecraft and comets by exploiting regions in space where motion is very sensitive (or chaotic). It also provides an introduction to celestial mechanics, dynamical systems, and dynamical astronomy. Bringing together wide-ranging research by others with his own original work, the author argues that regions supporting chaotic motions, termed weak stability boundaries, can be estimated. This method was first applied in 1991, when Belbruno used a new route developed from this theory to get a stray Japanese satellite back on course to the Moon, verifying his theory and representing the first application of chaos to space travel. Since that time, the theory has been applied in other space missions, and NASA is implementing new applications under Belbruno's direction. This book is a resource for graduate students and researchers in the disciplines concerned as well as practitioners in fields such as aerospace engineering.



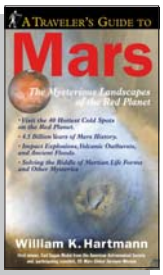
The Modern Moon: A Personal View. By Charles A. Wood. Sky Publishing Corporation, 2004. 228 pp., Hardcover, $44.95. *skyandtelescope.com*

Charles Wood's Lunar Notebook column in *Sky & Telescope* has been delighting readers for years. Now Wood brings his insightful and clear prose about our closest celestial neighbor to you in this new book. Drawing on both traditional telescopic observations of the Moon and the modern explorations of the Apollo, Clementine, and Lunar Prospector missions, *The Modern Moon: A Personal View* is an authoritative guidebook that tells readers both what to look for and why to look. Set up your telescope and let Wood unravel the Moon's complex past as you gaze at lunar vistas.



Assessment of Mars Science and Mission Priorities. By the Committee on Planetary and Lunar Exploration, National Research Council. National Academies Press, 2003. 144 pp., Paperback, $35.00. *www.nap.edu*

Mars occupies a special place in the U.S. program of space exploration, as well as in the minds of the public, because it is the most Earth-like planet in the solar system and the place where the first detection of extraterrestrial life seems most likely to be made. This report presents and reviews nine topics that comprehensively describe contemporary Mars science, working from the interior of the planet outward. Other topics discussed in this report include the rationale for the collection and return of samples from Mars and the priorities in the Mars Exploration Program in the light of earlier recommendations and current realities.



A Traveler's Guide to Mars: The Mysterious Landscapes of the Red Planet. By William K. Hartmann. Workman Publishing Company, 2003. 450 pp., Paperback, $18.95. *www.workman.com*

Factual, heavily illustrated, and in a size that makes it easy to carry around, this book brings together all the astonishing information scientists have recently learned about Mars and conveys it in the engaging, lively style that made Dr. Hartmann the first-ever winner of the Carl Sagan Medal for public communication of planetary science. Taken around the planet like tourists, readers will discover mysterious dry riverbeds, the largest volcano in the solar system (three times higher than Mount Everest), a possible ancient sea floor, giant impact craters, "the face on Mars," and other wonders. Throughout is a selection of photographs, maps, and paintings, including images from Mariner 9 and the Viking explorations, the Hubble Space Telescope, and the ongoing Mars Global Surveyor mission. Four gatefolds show the latest topographic maps of the entire martian surface, and sidebars advise readers on what to wear and landing procedures.

DVDs

Eyes on Mars. By Space Holdings Corporation, 2003. 162 minutes, $19.95. *www.starrynight.com*

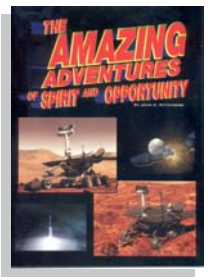
Join the adventure as the rovers explore Mars in this DVD from the creators of Starry Night astronomy software. Explore the mysterious past and fascinating future of the Red Planet. With more than two-and-a-half hours of content, it presents a documentary about the ongoing quest to fully understand the mysteries of Mars; a 3-D computer-generated simulation of a Mars mission, detailing the launch, flight, and landing of the Mars Exploration Rovers; and a look at Mars missions of the past — the successes and the failures — and the robotics we sent there. Also included are a Mars gallery with artists' renderings of martian landscapes and interviews with 16 guest experts who answer questions about life on Mars, water on Mars, and other enduring mysteries.

Online Resources

Exchanging Messages with Alien Civilizations: A Resource Guide. By Andrew Fraknoi.
www.astrosociety.org/education/family/resources/seti.html

As humanity actively searches for messages from other civilizations among the stars, both physical and social scientists have begun to give some thought to the form that their message and our answer might take. In other words, how will they "speak" our language, and how will we reply in theirs? Provided in this annotated resource guide are print and Web resources that investigate what people have been thinking about this topic, together with a few general references on the scientific search for extraterrestrial intelligence (SETI).

NEW FOR KIDS!!!



The Amazing Adventures of Spirit and Opportunity. By John C. Wittenberg. Aerospace1 Publications, 2004. 20 pp., Paperback, $14.99.

Written in comic-book style, this 20-page paperback book features facts and information about the two latest Mars rovers, Spirit and Opportunity. Included are dozens of color photos and illustrations that explain how we got to the Red Planet and how we are getting such great pictures back here on Earth. The book also introduces the little girl who named the rovers for NASA. A fun read for both kids and adults.

Cosmic Decoders Family ASTRO Kit. By Family ASTRO, Astronomical Society of the Pacific, 2003. $12.95. www.astrosociety.org

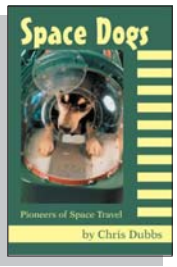
Play four games in one — Build A Galaxy, Telescope Trouble, Distance Derby, and Galactic Gobble — with this new card set from Family ASTRO. Cosmic Decoders includes a deck of 72 cards featuring beautiful color images of cosmic objects and some well-known telescopes. The game focuses on how astronomers "decode" light from space to learn about the universe and how we might decode radio waves from possible alien civilizations out there. Fun for the whole family!

Stargo Game. By DaMert Company, 2004. For 2 or more players, ages 6 to adult, $14.99. www.damert.com

It's classic bingo with cosmic fun! Become familiar with stars, galaxies, and constellations in no time! Two sides to each Stargo game card offer two ways to play bingo and learn, either by completing patterns in one constellation or by testing your memory against a card of 24 different constellations. Take the glow-in-the-dark cards and enclosed bonus compass outdoors after dark for some real live stargazing. Includes glow game cards, 48 colored "call" stars, 120 yellow "marker" stars, storage pouch, compass, instructions, and constellation facts.

LEGO Discovery Space Kit. By LEGO, 2004. Ages 10 to adult, $174.96. www.lego.com

Explore the solar system! Blast off with this out-of-this-world LEGO Discovery Space Kit. The five-model collection includes LEGO replicas of the International Space Station (162 pieces), Saturn V Moon Mission (178 pieces), Mission to Mars (417 pieces), Space Shuttle Discovery (826 pieces), and the new Mars Exploration Rover (858 pieces). Kits also sold separately.



Space Dogs: Pioneers of Space Travel. By Chris Dubbs. Writer's Showcase Press, 2003. 108 pp., Paperback, $11.95.

Back when scientists knew nothing about space travel and rockets were new, the space dogs of the Soviet space program rode rockets to the edge of space and into Earth orbit. From 1951 to 1966, these pioneer space travelers occupied the world stage, blazing trails as the first astronauts. Their flights taught scientists how living beings reacted to rocket travel and tested the equipment that would be used for human space flight. Although some of the dogs won worldwide fame, most worked and died in obscurity, but all were pioneers of space travel. This book discusses the training, the early flights, the tragic accidents, the fame that came to the program after the launch of Laika in Sputnik 2, and the final flights leading up to the first manned flight. Also included are never-before-published photos from the archives of Novosti, the Russian News Agency.

CALENDAR 2004

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

May

17–21 **Eighth International Conference on Space Operations**, Montreal, Canada. *http://www.spaceops2004.org/index_e.shtml*

17–21 **2004 Joint Assembly AGU, CGU, SEG and EEGS**, Montreal, Canada. *http://www.agu.org/meetings/sm04/*

19–21 **Planetary Nebulae Beyond the Milky Way,** ESO — Garching, Germany. *http://www.eso.org/gen-fac.meetings/extgalpn04/*

20–22 **23rd Annual Society for Scientific Exploration Meeting**, Las Vegas, Nevada. *http://www.scientificexploration.org/meetings.html*

23–28 **Imaging and Geospatial Information Society: 2004 Annual Confernce,** Denver, Colorado. *http://www.asprs.org/denver2004/index.html*

30–June 3 **204th American Astronomical Society Meeting**, Denver Colorado. *http://www.aas.org/meetings/aas204/*

June

4–6 **3rd International Workshop on Cometary Astronomy**, Paris, France. *http://www2.iap.fr/saf/IWCAIII/*

9–11 **GeoMod 2004: From Mountains to Sedimentary Basins**, Emmetten — Lake Lucerne, Switzerland. *http://www.ogs.trieste.it/GeoMod/*

14–19 **Physics and Astrophysics in Space,** Frascati, Italy. *http://www.roma2.infn.it/iwfs04/iwfs.html*

27–July 2 **Eleventh International Symposium, Water Rock Interaction**, Saratoga Springs, New York. *http://www.outreach.psu.edu/C&I/WRI/*

July

4–9 **9th Symposium of SEDI**, Garmisch-Partenkirchen, Germany. *http://www.simons-rock.edu/~bergman/sedi/*

5–9 **Cool Stars, Stellar Systems, and the Sun 13**, Hamburg, Germany. *http://www.hs.uni-hamburg.de/cs13/index.html*

5–9 **AOGS 2004: Effects of Space Radiation on Solar System Ices,** Suntec, Singapore. *http://www-691.gsfc.nasa.gov/cosmic.ice.lab/aogs/*

11–6 **The Astrophysics of Cataclysmic Variables and Related Objects,** Strasbourg, France. *http://astro.u-strasbg.fr/cvconf/*

12–15 **IAGA/ICMA Workshop, Vertical Coupling in the Atmosphere/ Ionosphere System**, Bath, England. *http://www.bath.ac.uk/elec-eng/IAGA2004.htm*

12–16 **Bioastronomy 2004 — Habitable Worlds**, Reykjavik, Iceland. *http://www.bioastronomy2004.os.is/*

12–23 **XXth Congress of the International Society for Photogrammetry and Remote Sensing**, Istanbul, Turkey. *http://www.isprs2004-istanbul.com*

16–18 **Return to the Moon V: This Time We Stay!**, Las Vegas, Nevada. *http://www.space-frontier.org/Projects/Moon/rtm2004.html*

18–25 **35th COSPAR Scientific Assembly**, Paris, France. *http://www.copernicus.org/COSPAR/COSPAR.html*

20–23 **Oxygen in the Terrestrial Planets**, Santa Fe, New Mexico. *http://www.lpi.usra.edu/meetings/otp2004/*

26–29 **Dust Disks and the Formation, Evolution and Detection of Habitable Planets**, San Diego, California. *http://planetquest1.jpl.nasa.gov/TPFDarwinConf/*

August

2–6 **Astrophysics in the FAR Ultraviolet: Five Years of Discovery with FUSE**, Victoria, British Columbia. *http://fuse-conference.pha.jhu.edu/*

2–6 **67th Annual Meeting of the Meteoritical Society**, Rio de Janeiro, Brazil. *http://www.cbpf.br/~metsoc04/*

16–21 **Meteoroids 2004**, London, Ontario, Canada. *http://aquarid.physics.uwo.ca/meteoroids2004/*

20–28 **International Geological Congress,** Florence, Italy. *http://www.32igc.org/default1.htm*

September

8–11 **High Energy Astrophysics Division — AAS**, New Orleans, Louisiana. *http://www.confcon.com/head_2004/head_2004.html*

13–17 **Remote Sensing Europe 2004**, Maspalomas, Gran Canaria, Spain. *http://www.spie.org/Conferences/Calls/04/ers/*

20–24 **International Geoscience: A Remote Sensing Symposium (IGARSS)**, Anchorage, Alaska. *http://www.ewh.ieee.org/soc/grss/igarss.html*

28–30 **Space 2004 Conference and Exhibit,** San Diego, California. *http://www.aiaa.org/space2004/*

October

10 –15 **Society of Exploration Geophysicists — International Exposition and 74th Annual Meeting**, Denver, Colorado. *http://meeting.seg.org/*

11–13 **New Windows on Star Formation in the Universe**, College Park, Maryland. *http://www.astro.umd.edu/october/2004/2004.html*

11–15 **Second Conference on Early Mars: Geologic, Hydrologic and Climatic Evolution and the Implications for Life**, Jackson Hole, Wyoming. *http://www.lpi.usra.edu/meetings/earlymars2004/*

November

1–3 **Space Resources Roundtable VI**, Golden, Colorado. *http://www.mines.edu/research/srr*

7–10 **Geoscience in a Changing Worl: GSA Annual Meeting & Exposition**, Denver, Colorado. *http://www.geosociety.org/meetings/2004*

8–12 **36th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society**, Louisville, Kentucky. *http://dps04.org*

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http://www.lpi.usra.edu/publications

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	S-GEOL	SHUTTLE VIEWS THE EARTH: GEOLOGY FROM SPACE **(40 slides)** ***last chance!***	$10.00	
	S-CLEM	CLEMENTINE EXPLORES THE MOON, SECOND EDITION **(35 slides)** ***last chance!***	$10.00	
	S-HAWAII	VOLCANIC FEATURES OF HAWAII AND OTHER WORLDS **(40 slides)** ***last chance!***	$10.00	
	TG-3DTCD	TEACHER'S GUIDE TO THE 3-D TOUR OF THE SOLAR SYSTEM **(CD-ROM)**	$5.00	
	C-ATLAS	3-D TOUR OF THE SOLAR SYSTEM (version 2.0) **(CD-ROM)**	$10.00	
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