The PLANETARY REPORT

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Saturn's Icy Moons

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

In 1980, as the two *Voyager* spacecraft were on their way to Saturn, we started an organization dedicated to ensuring that humanity's exploration of the solar system did not end at the sixth planet from the Sun. There was, at that time, a real danger that the political will to explore the universe around us had failed. With The Planetary Society, we were able to demonstrate that the popular will to see what lay beyond the next planet was still strong and kicking.

The popular will prevailed, and we reap the results today. Just look at all the moons we cover in this issue of *The Planetary Report*! In 1980, there were 11 known moons of Saturn; in 2005, Saturn boasts 34 named moons, with 12 more waiting in the queue. Every day, *Cassini* returns more images of the Saturnian system, following the trail blazed by *Voyager* 25 years ago.

We are looking at Earth's own Moon again, with an eye to returning there in person. We are not just wondering if there are any planetary systems besides ours; we are searching for and finding them. We are reveling in the overwhelming richness of nature and its potential to awe us with every new discovery.

In a very real way, The Planetary Society focused the public will to make all this happen. Let's hope our next 25 years are just as successful!

—*Charlene M. Anderson*

On the Cover:

Cassini images taken on December 31, 2004 were combined to make this near-true-color view of Saturn's moon Iapetus. This image, taken at a distance of about 172,900 kilometers (107,400 miles) shows the northern part of the moon's dark Cassini Regio. The large impact basin visible here is 400 kilometers (250 miles) in diameter. This image has been rotated so that north is to the right.

Image: NASA/JPL/Space Science Institute

Features

Departments

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Members' Dialogue

Refreshing Reminder

Thank you for publishing "Miranda: Shattering an Image" in the March/April 2005 issue of *The Planetary Report*. Many people (myself included) are not old enough to remember the *Voyager* missions, so it is refreshing to be reminded of some of the more obscure locales they visited.

Galileo has since been sent to Jupiter, and *Cassini* to Saturn, so the beauty and mystery of those systems are still fresh in mind, but we have not yet dedicated any [new] missions to Uranus' or Neptune's systems. Articles like "Miranda" help keep up awareness about the amazing places still waiting to be explored.
—BRIAN ALTMEYER,
Rancho Cucamonga, California

Project Daedalus

In the Members' Dialogue section of your March/April 2005 issue, Fabian Stretton states that the Project Daedalus spacecraft was designed to reach Sirius in 12 years. This is not true.

The objective of Project Daedalus, which was developed by members of the British Interplanetary Society from 1973 through 1978, was to travel to Bernard's Star, a red dwarf 5.9 light-years away. The projected mission time, using helium-3 mined from the atmosphere of Jupiter, was 50 years. This was short enough so that some of the original designers and engineers would still be alive when the spacecraft reached its destination.

Sirius is 8.7 light-years away. Sirius was not the destination of the Project Daedalus craft, and even if it had been, it would have taken almost 75 years for it to reach Sirius.
—ERIK ZAVREL,
Kenosha, Wisconsin

Fragrance Free

The otherwise excellent "A World Revealed: *Huygens*' Images of Titan," in the March/April 2005 issue of *The Planetary Report*, makes reference to methane as a "smelly" or "noxious" compound. Actually, pure methane gas is essentially odorless, and it is poisonous only in the sense that it can act as an asphyxiant, displacing oxygen in the air.

The odors we detect in connection with naturally occurring methane in swamps, in dumps, and in agriculture are contaminants resulting from biological processes. The strong smell we associate with natural gas, which is roughly 95 percent methane, is from ethyl mercaptan, an odiferous compound deliberately added to make a gas leak detectable.

Titan might well be a smelly place, thanks to the complex hydrocarbon chemistry going on in its atmosphere, but it won't be because of the presence of methane.
—CHARLES GALE,
Roswell, Georgia

Reduce Human Error

It was wonderful to hear the news that *Huygens* was successful, and then to see the images and everything. It was a triumph for ESA, for NASA, and for the world. However, the ensuing news that a single missing command lost all the A-stream data and, thus, half the pictures, shows that this great success was, in fact, nearly a disastrous failure.

Combined with the error over the Doppler frequency changes, which were forgotten in the receiver design, and the need to redesign the *Cassini* flyby to have any chance of returning useful data, it shows that mission designers and planners are still unable to ensure that the really basic things, like testing to confirm all commands are correct, are done. Given the *Genesis* (sensors upside down), *Mars Climate Orbiter* (metric to English unit muddle), and *Mars Polar Lander* (landing test sequence) failures, the pattern is easy to see. Human error is the main cause.

If the taxpayers in Europe and the United States are going to support expensive missions, human error must be reduced. It is simply not good enough to hold an investigation afterwards. I am a dedicated supporter of such missions, but mistakes like these will lose public support, which cannot be regained.
—LORD KIMBERLEY,
Buntingford, Herts, England

In General

Great job on the March/April issue. Once again you've provided insightful information on both recent and historical events.
—CHRIS MARTEL,
Plymouth, Michigan

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tps.des@planetary.org

We Make It Happen!

by Bruce Betts

Sounds of the Solar System

The Planetary Society has become the source for true sounds of the solar system (see *planetary.org/sounds*). Over the years, various planetary data have been artificially converted to sound, from radar data to plasma wave data. The Planetary Society, however, has been involved with all missions that have had acoustic sensors to detect true sound waves. We have long been able to "see" other planets through pictures, but these are the first attempts to let humans use another key sense, to "hear" other worlds.

Mars Microphone: The Beginning

In 1998, The Planetary Society's Mars Microphone became the first privately funded experiment to fly on a NASA planetary mission. It would have been the first ever to hear sounds on Mars, which would have included spacecraft noises and also possibly wind, sand, atmospheric discharges, or other natural sounds. Unfortunately, it was on *Mars Polar Lander*, a mission that failed. But the project gave us valuable experience with providing flight hardware to missions. We also connected with Greg Delory at UC Berkeley. He is the scientist who built the microphone and was ready to process its data, and he continues to be The Planetary Society's go-to guy on planetary sounds.

The Sounds of Titan

The *Huygens* Atmospheric Structure Instrument on board the European Space Agency's *Huygens* probe that successfully landed on Saturn's moon Titan in January 2005 carried an acoustic sensor designed to listen for thunder. But there were no clear plans to convert the data to sound that you could actually hear, something not necessary for scientific analysis. The Planetary Society offered to help convert the data to sounds that could be made available to the public. Again in partnership with Greg Delory, we were able to produce sounds that you can hear on our website. As you listen, ponder how amazing it is that you are hearing sounds from one billion miles away!

The First Planetary Sounds

Although the Mars Microphone was the first instrument flown specifically to let people hear the sounds of another world, it was not the first acoustic sensor to fly. That distinction belongs to the GROZA instruments on board the Soviet *Venera 13* and *14* Venus landers. The Planetary

What's Up?

In the Sky

Venus, in the West after sunset, is the brightest starlike object in the sky. Saturn, dimmer and more yellowish, is sinking toward the West in the early evening until it disappears in early July. Mercury, also in the West after sunset, appears in mid-June. Don't miss Venus, Mercury, and Saturn within 1.5 degrees of each other on June 25 and Mercury and Venus less than 0.2 degrees apart on June 27 (use binoculars for better view). Jupiter is extremely bright in the South in the early evening. Mars is in the Southeast at dawn, brightening and growing higher with time.

Random Space Fact

Temperatures at the center of the Sun reach nearly 15,000,000 degrees Celsius.

Trivia Contest

Our January/February contest winner is Darren Brown of Havre de Grace, Maryland. Congratulations!

The Question was: To the nearest micron (micrometer, or one millionth of a meter), how thick is the Mylar-like material that makes up the solar sails on The Planetary Society's *Cosmos 1* spacecraft?

The Answer: 5 microns—about 1/4 the thickness of an average trash bag.

Try to win a free year's Planetary Society membership and a Planetary Radio T-shirt by answering this question:

Comets often have two distinct, significant tails. What are these called?

E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 65 North Catalina Avenue, Pasadena, CA 91106. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one).

Submissions must be received by August 1, 2005. The winner will be chosen by a random drawing from among all the correct entries received.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science fiction guests, listen to Planetary Radio at *planetary.org/radio.*

Society recently contacted GROZA's principal investigator Leonid Ksanfomaliti, an old friend of the Society from the Space Research Institute in Moscow, and asked if these data had ever been converted to sound. They had not. At the Society's request, he generously pulled out the old data and has begun the process of converting the data to sound. These Venusian sounds will soon appear on The Planetary Society's website.

The Future and the Marsinator

The Society is working to get microphones to Mars and other places in the solar system, negotiating with future missions. We'll keep you posted. In the meantime, enjoy the solar system sounds so far. While you are at it, also enjoy the results of the "Marsinator" on our website. We have taken a variety of people's voices, including those of Ray Bradbury and Bill Nye, and converted them to how they would sound on Mars. The results are as amusing as they are informative.

Heads Up for a Deep Impact!

The Planetary Society will hold Comet Bash 2005 in the Pasadena area on Sunday, July 3, 2005 to celebrate and watch the live, high-speed impact into Comet Tempel 1 by NASA's *Deep Impact* mission. You are invited. Set the date aside. More information is available on our website.

Bruce Betts is director of projects at The Planetary Society

THE MOON:

WHAT WE KNOW AND WANT TO KNOW

BY JAMES D. BURKE

Cold lantern of the winter night, inspirer of origin myths in every ancient civilization, long known to be another world, the Moon still guards her secrets.

Here, I give a review of accepted lunar knowledge and then take us into the near future, when, after decades of abandonment, the Moon may again become a province of our human domain.

This tale of centuries, of the halting and sometimes wandering growth of lunar knowledge, is a bright thread in the tapestry of science and indeed of Earth's civilizations as people continue to wonder whence we came and whither we are bound.

Most of the peoples whom we now regard as primitive carefully observed the Moon's motions, its waxing and waning, and the markings on its face. Based on these observations, they created origin theories, often independent but remarkably similar. In both Eastern and Western societies, people thought that at the creation, all was darkness. Then First Woman—or an animal deity, or the God of the King James Bible's glorious Genesis poem—decreed, "Let there be light," and there was light. Thence onward, the Moon, in her many guises and names, ruled the night.

By at least the time of early dynasties in China and Mesopotamia, more than 3,000 years ago, the Moon's motions had been recorded accurately and lunar calendars made. Even today, the desert religions preserve the lunar rhythm in their festivals and fasts. Not only did ancient people study the motions of the Moon, noting its synchrony with tides and human fertility, but they also observed and built ideas upon the markings on its face. Myths involving a rabbit are irresistibly recalled when one gazes at the full Moon and traces the outline of the great dark plains, the maria, in their contrast to the light-toned highlands.

Then, as in so many other fields of natural philosophy, came the flowering of knowledge in Greece: observers determined the Moon's size, its distance from Earth, and its true nature as a globe, not just a disk moving in the sky. From then on, even though centuries were to pass before Galileo, Kepler, Descartes, Newton, Kant, and Halley lived, humanity knew the Moon as never before, and the concept of a plurality of inhabited worlds hovered at the edge of science.

EARLY SCIENTIFIC OBSERVATION

Telescopic mapping, culminating in the great lunar atlas compiled in the 19th century at observatories in Berlin and Athens, codified the classical names that now adorn the Moon—the vast lava plains Ocean of Storms, Sea of Tranquility, and Bay of Rainbows; the great craters Plato, Aristarchus, and Copernicus; and so on. The main lunar controversy of those times was about vulcanism versus impact as the cause of landforms on the Moon. In 1667, Robert Hooke had experimented by dropping balls into mud and by boiling it to test these alternatives. Later observers continued to take sides, all the way into the 20th century, when the question was settled definitively in favor of impact as the primary agent. With that realization and other observations, it was driven home to scientists that impact has been a dominant process throughout the solar system, that huge impacts continue to this day, and hence that our world and its civilizations remain at risk.

As astronomy advanced beyond the Sun's neighborhood and outward into the realm of stars and then the Island Universes—galaxies, now known to be the fundamental unit in the architecture of the cosmos—the Moon and the Sun's planets were largely bypassed as objects of inquiry. Still, in the early 20th century, a few persistent observers continued to explore the Moon from Earth using the new techniques of infrared and radio astronomy, spectrometry, and polarization of light. Gradually, it became evident that the Moon's surface is very strange—almost as dark as black coal, extremely rough on a microscopic scale, and a very good thermal insulator.

Ansel Adams took "Moon and Half Dome" in 1960 from California's Yosemite National Park.

Right: Here is a fine example of the best lunar images that can be obtained from Earth, showing the contrast between maria and highlands and revealing the stratigraphic relations that enabled geologists to label the relative ages of lunar provinces long before the start of lunar flight missions. *Image: Lick Observatory*

Below: This map of the lunar surface compared the observations of 17th-century astronomers Johannes Hevelius and Giovanni Battista Riccioli. It appears in* Atlas coelestis, *the atlas by Johann Gabriel Doppelmayr and Johann Baptist Homann (Nuremberg, 1742).
Map: Reprinted courtesy of Adler Planetarium and Astronomy Museum

THE MOON IN THE SPACE AGE

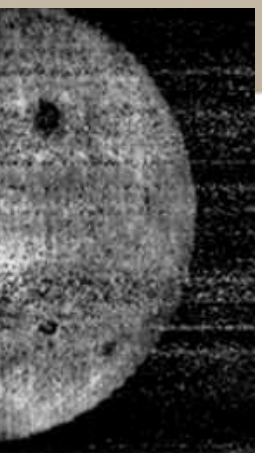
Once spacecraft began making local measurements, these properties were explained as results of the endless rain of impacting objects, together with energetic radiation and particles from the Sun and beyond. The term *regolith* (Greek *regos*, or blanket; and *lith*, or rock) began to be applied to the Moon's ubiquitous surface coating of smashed and pulverized materials comprising particles of all sizes, from the finest dust to huge boulders.

In parallel with the progress of ground-based lunar mapping and other lunar sciences, indeed possibly driving them, lunar science fiction flourished from the 17th through early 20th centuries, spreading the idea that one day humans would know what is on the Moon's unseen far side and perhaps be able to travel to and live upon the Moon. By the 1930s, this dreaming and yearning began slowly to evolve into real rocket development.

Then, with stunning speed, driven by war and the threat of war, came the heyday of lunar rocketry—a brief, splendid episode in humanity's reach into the cosmos. The United States and the Soviet Union engaged in a vigorous, peaceful contest using lunar robotic and human missions as demonstrations of national strength.

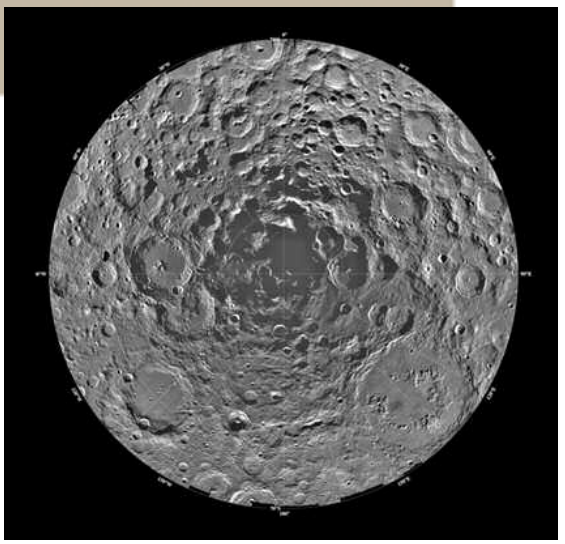
Historians now regard that short golden age as an anomaly, an excursion from what would be expected in the normal advance of space exploration. Happily, that anomaly, with the long dry spell that followed it, is now past. A modest lunar renaissance is in progress, with some promise of a return, if not to the wild risks and joy of the 1960s, at least to a healthy and sustained human advance toward becoming a two-planet species.

The geopolitical competition yielded a cornucopia of new knowledge of the Moon. Ending centuries of speculation, the Soviet *Luna 3* in 1959 gave the first images of the unseen far side, revealing that it consists mostly

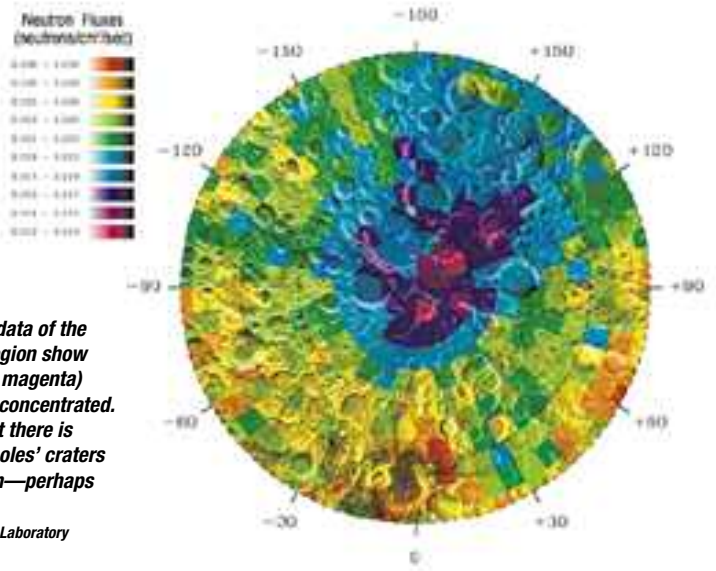


Left: Humanity got its first glimpse of the Moon's far side in October 1959, when the Soviet spacecraft* Luna 3 *returned this epic photo.
Image: USSR/National Space Science Data Center

Left: The* Galileo *spacecraft captured this partial portrait of the lunar far side on December 9, 1990 from a distance of 560,000 kilometers (about 350,000 miles). The dark spot at center is Mare Oriental (about 1,000 kilometers, or 600 miles, in diameter), which sits on the western limb of the Moon's near side—a region barely visible from Earth.
Image: JPL/NASA



Right: This view, centered on the Moon's south pole—a mosaic of about 1,500* Clementine *images—shows the shadowed regions there. The south pole is especially interesting because the area that remains in shadow is much larger than that at the north pole. Scientists have long thought that water ice might exist in the cold shadows of the craters at the Moon's poles. The large feature at lower right is the Schrodinger Basin, which is 320 kilometers (about 200 miles) in diameter.
Mosaic: United States Geological Survey



Right*: Lunar Prospector *data of the Moon's northern polar region show the areas (dark blue and magenta) where hydrogen is most concentrated. To tell us definitively that there is water ice hidden in the poles' craters will take another mission—perhaps a surface rover.
Illustration: Los Alamos National Laboratory

of light-toned highlands. Later Soviet and American missions elucidated the Moon's geologic, mineral, chemical, and geophysical character, showing it to have undergone enormous heating episodes in the distant past but now to be a satellite with no substantial atmosphere whose internal heat engine is dead.

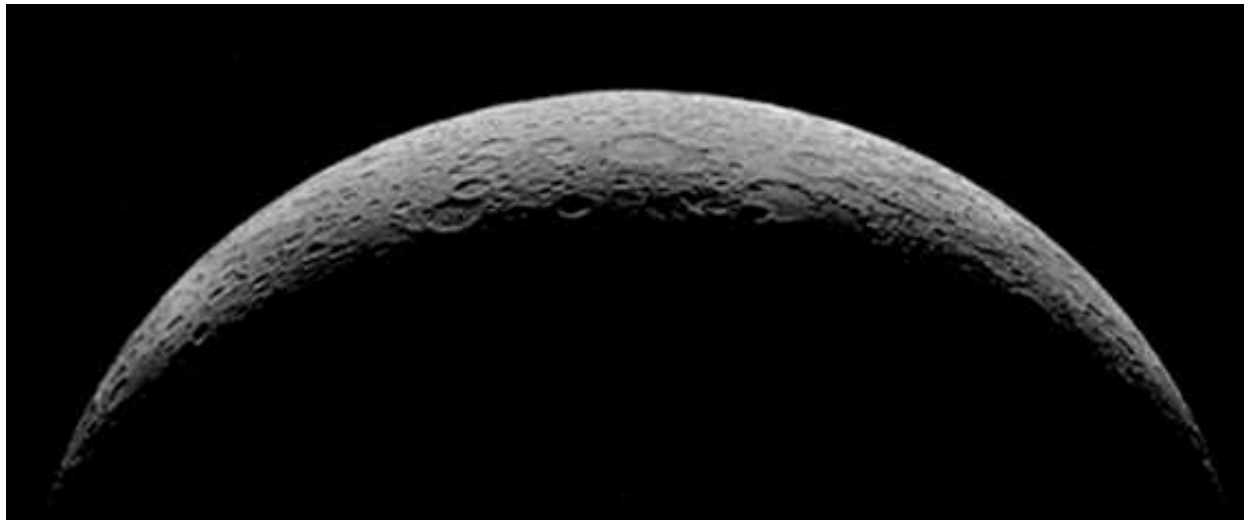
FORMATION OF THE MOON

Taking all of the new observations into account, scientists have arrived at a broadly agreed-on picture of the Moon's evolution. Within a few hundred million years of the solar system's formation (shown by ancient meteorites to have occurred some 4.55 billion years ago), the proto-Moon's outer layers were melted by the heat of its aggregation from smaller objects, forming a magma ocean in which heavier minerals sank and lighter ones floated. The resulting crust continued to be bombarded. Huge impact basins formed. Hundreds of millions of years later, the heat of internal radioactivity caused a renewed episode of partial melting. Most of the near-side basins were flooded with enormous flows of very fluid lava, forming the iron- and titanium-rich maria in contrast to the aluminum-rich, more ancient highlands.

Perhaps the Moon was left with a small core, but if so, it has long ceased to be a dynamo like the core of Earth. The Moon has only slight seismic activity, no evidence of widespread surviving vulcanism, and no global magnetic field. It is highly depleted in volatile elements, and the *Apollo* and *Luna* samples have never been affected by water.

So how did this all begin? For more than a century, scientists have debated whether the Moon (a) formed beside the proto-Earth in a gas-and-dust nebula around the nascent Sun, (b) was somehow spun out of the early Earth, or (c) wandered in from elsewhere and was captured. Each of these scenarios is contradicted by one or

The European Space Agency (ESA) launched the first of its Small Missions for Advanced Research in Technology, or* SMART-1*, to the Moon, on September 27, 2003. This mission is a test of solar electric ion propulsion and miniaturized science instrument technology. *Illustration: ESA/Medialab*



On November 12, 2004,* SMART-1 *took this picture as it approached the Moon from a distance of about 60,000 kilometers (37,000 miles). It is the first view of the Moon's far side taken by a European spacecraft. At the time this image was taken, the Moon was new and invisible from Earth. *Image: ESA/Space-X, Space Exploration Institute*

more of the available data sets. Unexpectedly, the *Apollo* and *Luna* observations did not settle the question. Indeed, they compounded the puzzle, and it was not until years later that a persuasive origin concept emerged—namely, the giant impact hypothesis.

In this imagined scheme, an object the size of Mars struck Earth a glancing blow, throwing out a huge spray of material from both bodies that eventually coalesced into the proto-Moon. Computer models show that this sequence of events is possible, and observational data are not in violent conflict with it, so it is a popular scenario—yet the whole truth may never be known.

Meanwhile, the long post-*Apollo* spell of ignoring the Moon was coming to an end. Japanese researchers obtained support for a series of lunar technology demonstration and scientific missions, and in the United

THE MOON SURROUNDED

After decades of abandonment, the Moon is suddenly the goal of as many as 10 orbiting spacecraft.

The European Space Agency's *SMART-1*, demonstrating solar-electric propulsion and other new technologies, has already arrived and is starting science operations.

The Japan Aerospace Exploration Agency is preparing two lunar missions: *Lunar-A*, which will deliver two seismic penetrators, and *SELENE*, which consists of a main orbiter carrying an elaborate suite of instruments and two small companion orbiters. Both will launch no earlier than 2006.

In a nongovernment effort, Transorbital, Inc. intends to launch an imaging orbiter in 2006 or 2007.

The Indian Space Research Organization's *Chandrayaan-1*, another large, multifunctional, remote-sensing orbiter, is scheduled for 2007.

The China National Space Administration's *Chang'e-1*, planned for launch in 2007, will carry a large suite of instruments for spectrometry, altimetry, and imaging.

The United States plans to launch a large Lunar Reconnaissance Orbiter in 2008. Additionally, the United States is considering a sample-return lander to the Moon's South Pole-Aitken Basin.

With this plethora of lunar missions suddenly before us, we at The Planetary Society are doing what we can to encourage coordination among the many people and agencies involved. —*JDB*

States, the remarkable, low-cost *Clementine* and *Lunar Prospector* orbiters were launched.

A fascinating finding of these two missions is their discovery of excess hydrogen near both lunar poles. As long ago as 1961, scientists predicted that volatile substances might survive in permanently shadowed polar regions. The neutron spectrometer on *Lunar Prospector* showed beyond doubt that some light element is anomalously concentrated within a meter of the polar lunar surface. Hydrogen is the most logical candidate.

People immediately speculated that this hydrogen signature indicates the presence of ice, and that may be true. If it is, the Moon's cold traps hold a valuable resource for a human lunar future. However, there are other explanations. The only way to be sure is to land, rove, drill, and analyze in the cold dark regions. Creating robots for this purpose is an obvious near-term goal.

THE MOON'S FUTURE

What of the farther future? In both the United States and Europe, serious planning is afoot toward using human lunar expeditions as a step on the road toward Mars. In other nations, including Russia, India, China, and Japan, new robotic lunar missions have been proposed and some approved. The European Space Agency's *SMART-1* is demonstrating solar-electric propulsion, having traveled slowly toward the Moon, entered lunar orbit, and started a variety of scientific observations there. With all these lunar actions worldwide, humanity is once more about to pick up the challenge of traveling beyond low-Earth orbit, this time with a firm intention toward sustained living and working on the Moon.

As these new ventures arise, what are our next desires for lunar knowledge? Scientists already are answering this question in their responses to calls for experiment proposals. Among other things, they want deeper knowledge of moonquakes. A Japanese orbiter is intended to drop seismic penetrators into the regolith. Other proposals include different ways to learn more about the Moon's interior—for example, by returning samples deeply excavated by large impacts. Accurate topographic mapping, especially in the polar regions, is essential in preparation for precision landings of robots and then of piloted craft. And the putative ices must be investigated: Are they accessible and usable, or is the observed excess hydrogen merely a scientific curiosity?

During the next few years, we expect to see a new flowering of lunar science and, in parallel with that, a variety of lunar missions devoted more to engineering and operations. As people in the world's space agencies rise to the challenge of readying needed capacities for human missions to Mars, the Moon is to become their proving ground.

With an energetic and sustained program of lunar development, we will be moving irrevocably into the cosmos. Where the journey ultimately will lead no one can say, but it is certain that in some unknown but readily imagined future, humans will find ways to live safely and productively in the lunar environment, bringing their skills and ideas with them into another world. Then it is possible that a whole new phase in civilization may develop—the branching of history into one stream on Earth and another on the Moon.

James D. Burke is technical editor of The Planetary Report.

CASSINI'S CORNUCOPIA OF 7 SATELLITES IN 7 MONTHS

BY AMANDA R. HENDRIX
AND JONATHAN I. LUNINE

ON FEBRUARY 16, 2005, THE *CASSINI* SPACECRAFT MARKED A MILESTONE: AFTER ORBITING SATURN FOR 7 MONTHS, *CASSINI* HAD RETURNED MORE DETAILED VIEWS OF NEARLY ALL THE MAJOR SATELLITES OF SATURN THAN THE GREAT *VOYAGER* HAD GIVEN US A QUARTER CENTURY AGO. WE NOW PRESENT TO YOU PHOEBE, TETHYS, DIONE, IAPETUS, MIMAS, RHEA, AND ENCELADUS, THE SEVEN ICY SATELLITES SO FAR MET BY *CASSINI*, EACH ONE A DISTINCTIVE WORLD WORTHY OF EXPLORATION. (OF COURSE, SATURN'S GIANT MOON, TITAN, ALSO HAS YIELDED UP SOME OF ITS MYSTERIES TO *CASSINI* AND THE PROBE *HUYGENS*, BUT THAT STORY WILL BE TOLD IN THE JULY/AUGUST 2005 ISSUE OF *THE PLANETARY REPORT*.)

CASSINI IS TARGETED TO EXPLORE THE SATURNIAN SYSTEM FOR THE NEXT FOUR YEARS, SO THE IMAGES WE PRESENT ON THESE PAGES REPRESENT ONLY THE FIRST WAVE OF DISCOVERY. STAY WITH US AS WE CONTINUE TO EXPLORE THE LORD OF THE RINGS AND ITS RETINUE OF MOONS.

Tiny Phoebe appears to be a dense, rocky object, possibly captured from beyond Saturn's orbit. Scientists have suggested that Phoebe's dust is the source of the dark material on Iapetus—though whether this is actually the case is still not clear. *Mosaic: NASA/JPL/Space Science Institute*

JUNE 11, 2004: PHOEBE

On its way to enter orbit about Saturn, *Cassini* flew by tiny, distant Phoebe. This moon is so remote (about 215 R_S, or 13 million kilometers) that approach to Saturn was the one opportunity *Cassini* had for a good look at Phoebe. With its orbit tilted about 175 degrees, Phoebe rotates around Saturn in the opposite direction to that of the larger moons close to Saturn, and it is surely a captured object. Since Phoebe's discovery, astronomers have wondered where it came from. Being so small—214 kilometers (133 miles) across—and dark, Phoebe probably originated in a vastly different region of the solar system. But did it come from the asteroid belt between Mars and Jupiter or from the Kuiper belt in the outer reaches of the solar system, or from elsewhere in the solar system?

MOONS:

S AT SATURN

An enormous trench called Ithaca Chasma courses three quarters of the way around Tethys' circumference. Like Mimas, this heavily cratered world also sports a giant impact basin (named Odysseus and not visible here), but unlike Mimas' sharper-edged Herschel, Odysseus is flattened and appears much older. *Image: NASA/JPL/Space Science Institute*

Appearing as a blurry ball in *Voyager* images, Phoebe as revealed by *Cassini* from a distance of 2,068 kilometers (1,285 miles) is an extremely battered body. From ground-based spectroscopy, we knew that water ice was present at Phoebe; *Cassini* showed us that water ice is practically everywhere. At some crater rims, we saw clean, fresh water ice exposed. So much water ice suggests that Phoebe did not originate in the main asteroid belt, where there is very little water, but instead came from the outer solar system, at Jupiter's orbit or beyond, where water ice is abundant.

Another clue to Phoebe's origin is its bulk density of 1.6 grams per cubic centimeter. Pure water has a density of 1 gram per cubic centimeter. The average density of Saturn's intermediate-sized moons (hence excluding massive Titan) is 1.3 grams per cubic centimeter, so Phoebe is made up of a higher proportion of rock than most of its siblings. Its composition is closer to that of Pluto and of Neptune's moon Triton. *Cassini*'s flyby of Phoebe therefore may have been the first encounter with a body from the very farthest reaches of the solar system!

October 28, 2004: Tethys

Just 2 days after the first Titan flyby, *Cassini* flew by Tethys at a distance of 246,575 kilometers (153,215 miles). Although this is the most distant of the flybys we discuss here, it was close enough to improve upon the *Voyager* images. *Voyager* had shown Tethys to be a cratered body with regions of smooth plains, suggesting that in the past, materials that were heated and melted in the interior erupted and resurfaced this moon. *Voyager* images revealed the presence of Odysseus, an old impact basin 400 kilometers (250 miles) wide, whose shape appears flattened and subdued relative to a fresh crater of its size. Also seen in *Voyager* images was Ithaca Chasma, the large rift that may have been formed by the impact that created Odysseus.

Cassini confirmed the cratered nature of Tethys but revealed regions of grooved terrain, formed perhaps by extension of parts of the surface of the satellite in response to internal heating, as well as smooth plains where flows of liquid water or warm ice covered the original surface. If water-ice volcanoes (or "cryovolcanoes") did once erupt on Tethys, it might be because ammonia (NH_3) is mixed with water (H_2O) to lower water's melting temperature. As yet, ammonia has not been detected in the infrared spectra at any of the icy satellites, although it appears in the spectrum of the large Kuiper belt object Quaoar.

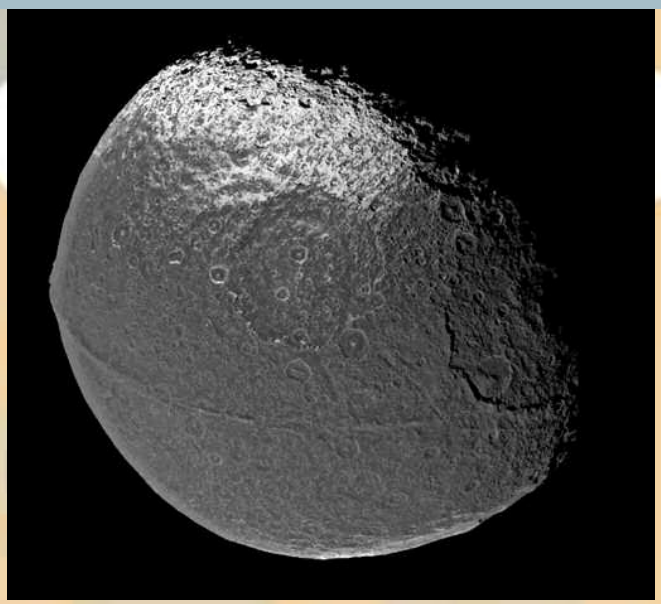
More recently, on March 9, *Cassini* flew within 83,000 kilometers (52,000 miles) of Tethys, providing the best-yet views of the Saturn-facing hemisphere and Ithaca Chasma. *Cassini* will keep looking for ammonia and other clues to Tethys' history, making several close passes by Tethys during the four-year tour, including on May 2, 2005 (50,000 kilometers or 30,000 miles); September 24, 2005 (33,000 kilometers or 20,000 miles); and June 27, 2007 (15,000 kilometers or 9,300 miles).

December 15, 2004: Dione

Two days after the second Titan flyby, *Cassini* encountered Dione at a distance of 72,070 kilometers (44,780 miles). Among the Saturn satellites, Dione is notable for its "wispy" terrain, first seen in less detailed *Voyager* images. Scientists have debated the nature of the wispy streaks, with some suggesting that they were erupted material that settled onto the surface. *Cassini* imaging showed that the wispy terrain actually is a series of large fractures whose cliff-like walls are extremely bright.

Both *Voyager* and *Cassini* revealed smooth plains that suggest recent eruptions of icy material. As with Tethys, ammonia probably is mixed with water to decrease its melting temperature so that it can flow from the interior.

Dione's surface appears to be brushed with markings that scientists thought were composed of thick ice deposits, but* Cassini *images have shown this younger, "wispy" terrain to be caused by bright ice cliffs created by tectonic fractures. *Mosaic: NASA/JPL/Space Science Institute*



Voyager *images of Iapetus showed us a world divided into two zones—dark and light. Now* Cassini*'s sharper eyes have revealed Iapetus to sport a unique, mountainous ridge around its equator on its dark side, which scientists have nicknamed the "belly band."* *Mosaic: NASA/JPL/Space Science Institute*

Future *Cassini* flybys that will capture more terrain in higher detail will occur on October 11, 2005 (1,000 kilometers or 600 miles); November 21, 2006 (72,000 kilometers or 45,000 miles); and September 30, 2007 (61,000 kilometers or 38,000 miles).

December 31, 2004: Iapetus

Since Jean-Dominic Cassini discovered Iapetus in 1671, we've known that this moon is unlike any other in the solar system. The leading hemisphere is very dark (reflecting only 4 percent of the light falling on it), while the trailing hemisphere is quite bright (reflecting 50 percent of incident light). The origin of this bizarre brightness dichotomy has puzzled scientists for centuries. One hypothesis is that the dark material is exogenic (derived from external processes), coming to this moon when impacts blasted dark material off Phoebe or other small, outer satellites of Saturn. Others have suggested that the dark stuff is endogenic (erupted from inside the satellite.) *Cassini*'s first flyby provided evidence for an exogenic origin, but Iapetus had new surprises in store for us!

Cassini flew by Iapetus at a range of 123,400 kilometers (77,000 miles), keeping its distance to avoid the possibility that the moon's gravity could throw the recently released *Huygens* probe off its course to Titan. This flyby focused on the leading hemisphere, allowing the spacecraft's instruments ample opportunity to investigate the dark terrain known as Cassini Regio.

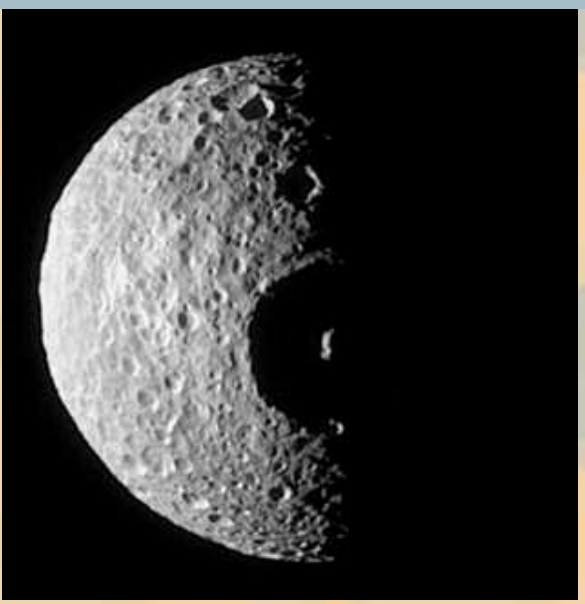
Cassini's images revealed large impact basins within the dark terrain. (Images taken from about 1 million kilometers [600,000 miles] in July and October 2004 first hinted the basins were there.) These later images show with shocking clarity how the dark material is distributed: it is mostly on the hemisphere facing the direction of motion of this moon in its orbit around Saturn, but coverage is less uniform away from the center of the hemisphere. In the bright region around the north pole, streaks of dark material are oriented in a north-south direction. Crater rims that face the equator are coated with the dark material, whereas polar-facing crater rims remain bright. This pattern of dark material is to be expected if the source were an impactor from elsewhere in the Saturn system that splashed across the face of Iapetus.

Most surprising, however, was the discovery of a huge ridge within the dark terrain that runs along Iapetus' equator. This "belly band"—faintly hinted at in *Voyager* images—is nearly 8 kilometers (5 miles) high and 20 kilometers (12.5 miles) wide. In some areas, the large ridge appears irregular and mountainous. Its presence suggests that Iapetus suffered through some sort of catastrophe to build such a huge ridge. It might not have formed on the equator—the satellite may have rotated slowly to bring this huge band into the plane of its orbit around Saturn.

The belly band raises anew the question of the dark material: could some of it have been expelled from the interior in the catastrophe that formed the belly band? If so, the persistence of ancient basins within the dark terrain suggests that whatever laid down the dark material did not destroy existing impact craters. Thus, we cannot say that the origin of Iapetus' bizarre appearance is fully resolved—we await the next close flyby, at a range of just 1,000 kilometers (600 miles), in September 2007.

January 15–16, 2005: Mimas and Rhea

Cassini's closest approach to Mimas was 107,640 kilometers (67,000 miles). *Voyager* images had revealed Mimas to be dominated by the 100-kilometer-wide crater Herschel, with its striking central peak. This giant dwarfs all other



The giant impact crater Herschel gives Mimas its distinctive eyeball look. But that eyeball is a bit squashed!* Cassini *observations of Mimas confirm that it is not a sphere but an ellipsoid measuring 418 by 392 by 382 kilometers (260 by 244 by 237 miles).
Image: NASA/JPL/Space Science Institute

craters on Mimas and gives this moon the nickname of the "Death Star." *Cassini* confirmed the heavily cratered character of the surface and also discovered a trench-like feature adjacent to Herschel, which may have been formed as a consequence of the giant impact that made Herschel.

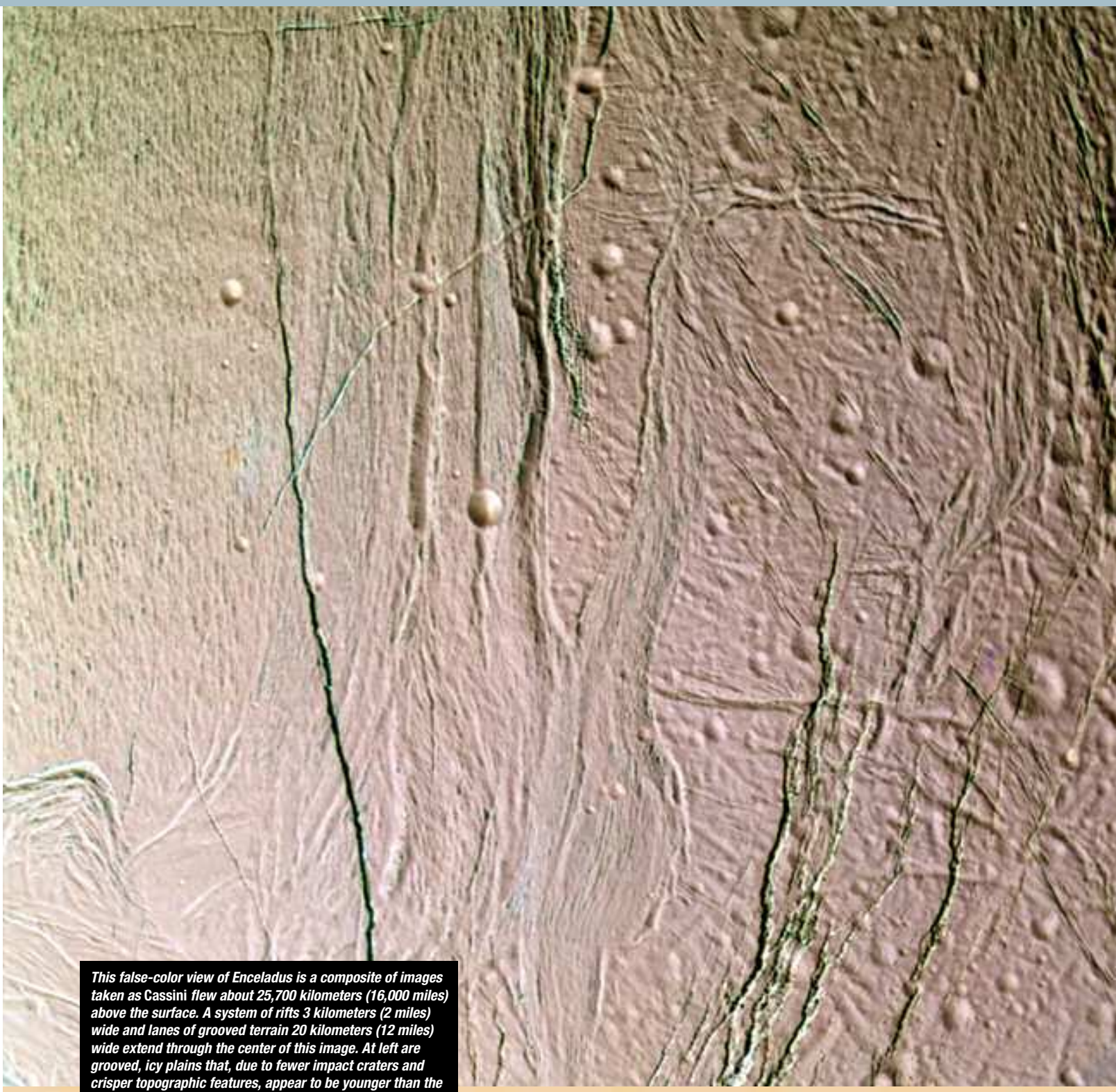
Mimas is likely geologically dead, having no apparent geologic features other than craters and being too small (radius of 196 kilometers) and icy to retain any heat from formation that could drive geologic processes. Generally, with icy satellites, brightness is associated with freshness, because bright surfaces usually are younger than dark ones. However, with Mimas, the surface is very bright even though it is old because it is made primarily of water ice and evidently hasn't been contaminated significantly by non-ice material. Also, because Mimas orbits Saturn within the E ring, small, bright ring particles likely coat its surface, keeping it bright despite its age.

Above: Mimas orbits against the blue backdrop of Saturn's northern latitudes in this true-color view taken by* Cassini *on January 18, 2005, about 1.4 million kilometers (870,000 miles) from Saturn. The dark lines on the planet are shadows cast by its rings. *Image: NASA/JPL/Space Science Institute*

Right: At first glance, Rhea, with its wispy terrain, looks a lot like Dione. It has yet to be discovered, however, whether Rhea's bright streaks are similar in nature to Dione's. After Titan, Rhea is Saturn's second largest moon. *Image: NASA/JPL/Space Science Institute*

The last close *Cassini* encounter with Mimas was on April 15, 2005 (85,000 kilometers or 53,000 miles). Others will be on August 2, 2005 (47,000 kilometers or 30,000 miles); May 26, 2007 (127,000 kilometers or 79,000 miles); and June 27, 2007 (92,000 kilometers or 57,000 miles).

Cassini flew by Rhea at a closest-approach distance of 154,030 kilometers (96,000 miles). *Voyager* images of Rhea had uncovered wispy terrain, similar to that seen on Dione. This *Cassini* flyby revealed a heavily cratered surface characterized by the streaky wisps and other linear features. There is no obvious sign of recent geologic activity, which we might have expected from this, the largest of the inner icy satellites (1,526 kilometers or 948 miles across), since larger moons retain heat more effectively than do smaller ones and hence should have more melted ice and geologic activity. Rhea's density is lower than the average for Saturn's icy moons, indicating that it has less heat-generating rock, which might explain the lack of activity. Upcoming Rhea observations by *Cassini* include flybys on November 26, 2005 (500 kilometers or 300 miles); January 17, 2006 (184,000 kilometers or 114,000 miles); March 21, 2006 (76,000 kilometers or 47,000 miles); May 27, 2007



This false-color view of Enceladus is a composite of images taken as Cassini *flew about 25,700 kilometers (16,000 miles) above the surface. A system of rifts 3 kilometers (2 miles) wide and lanes of grooved terrain 20 kilometers (12 miles) wide extend through the center of this image. At left are grooved, icy plains that, due to fewer impact craters and crisper topographic features, appear to be younger than the terrain at right.* *Image: NASA/JPL/Space Science Institute*

(177,000 kilometers or 110,000 miles); August 30, 2007 (5,000 kilometers or 3,000 miles); and November 16, 2007 (74,000 kilometers or 46,000 miles).

February 17, 2005: Enceladus

Cassini made its first flyby of Enceladus on January 16 at a distance of 207,000 kilometers (129,000 miles). On February 17, 2005, it flew much, much closer, only 1,265 kilometers (786 miles) up, and saw details as small as 40 meters on the surface of this enigmatic moon. With a diameter of only 520 kilometers (320 miles), Enceladus would not be expected to have retained internal heat after formation. However, one of *Voyager*'s surprises was the discovery of bright, smooth plains that suggest this moon

Tiny Enceladus stands out from the rest of Saturn's icy moons because of its mysterious geologic complexity. Enceladus' surface is inscribed with a tangle of linear features that reveal relatively recent geologic activity. Enceladus even seems to have a tenuous atmosphere. *Image: NASA/JPL/Space Science Institute*

has been recently resurfaced. This is startling for such a small, icy body!

As with other Saturnian moons, ammonia and water may be mixed on this icy satellite, which would allow ice volcanism because of the lowered melting temperature of water. Enceladus is locked into a 2:1 orbital resonance with Dione; that is, Enceladus orbits Saturn twice for every one orbit of Dione, so twice each time around, Enceladus is tugged away from a perfectly circular orbit, creating internal friction and hence tidal heating. This may provide enough continual internal heating in Enceladus to melt a portion of the ammonia-water ice.

Its *Cassini*-measured density also implies that Enceladus is richer in rock than the average for the Saturnian system. (Although Enceladus is nearly as rock-rich as Phoebe, its tight, regular orbit around Saturn suggests that it is not a captured body like Phoebe.) Typical solar system rock contains radioactive isotopes of potassium, thorium, and uranium, and their decay to stable isotopes should generate heat to add to that provided by tidal heating and the moon's formation from smaller chunks.

There is suggestive evidence that cryovolcanism involving ammonia and water is happening on Enceladus today. Saturn's E ring is densest at the orbit of this moon. The source of the ring could be material vented from the interior as a vapor or particle stream. Enceladus is so small that we wouldn't expect it to retain a substantial atmosphere, but measurements by the *Cassini* orbiter suggest the presence of a tenuous atmosphere of oxygen around Enceladus. This thin layer of gas is likely created by charged particles trapped in Saturn's magnetosphere slamming into the icy surface of Enceladus and liberating oxygen from water ice.

Cassini images from this flyby show a surface with far fewer craters than we see on other Saturnian icy moons, and in places there are none at all. At high resolution, the camera pictures show ropy flows and fracture patterns covering much of the surface. Some of the veinlike linear features look different in composition from, or may consist of different ice grain sizes than, surrounding terrain. Even the craters we do see appear distorted, as if the ice in which they formed had softened. Whether any of the craters could be vents through which volcanic gases and fluids escape requires detailed analysis of the new images.

Before this article went to press, *Cassini* flew by Enceladus on March 9, 2005, at a distance of 500 kilometers (300 miles). The closer flyby range allowed for the observation of details down to 20 meters in size. The images reveal that there is a range of ages of surfaces on Enceladus. Craters in older (more heavily cratered) regions are subdued and often criss-crossed by fractures. Regions on Enceladus termed "smooth plains" have been found by *Cassini* to exhibit intricate sets of fractures and topographic features.

No one has yet detected ammonia on Enceladus, although the ease with which the molecule is broken apart by ultraviolet light from the Sun may make it hard to find directly. This intriguing moon will be probed in even more detail on July 14, 2005 (from 1,000 kilometers or 600 miles) and March 12, 2008 (100 kilometers or 60 miles).

These first good looks at the icy moons of Saturn have sharpened the knowledge we gained from *Voyager*. For most of these little worlds, the closest flybys are yet to come. There are many questions we still need to answer: How was the dark material placed on Iapetus' leading hemisphere, and is it related to the belly band? Does Rhea show any signs of recent geologic activity, and if not, why not? Do any of these moons exhibit spectral features resulting from ammonia? Is Enceladus geologically active now? Is Enceladus indeed the source of the E ring, and if so, what is the mechanism?

Twenty-five years ago, *Voyager* raised many of these questions; *Cassini* just might answer many of them. But these moons are so evidently rich in complex histories that we may still be left with more questions than answers!

Amanda R. Hendrix is on the Cassini *Science Planning Team at the Jet Propulsion Laboratory and is a* Cassini *Ultraviolet Imaging Spectrograph team member. Her research interests include UV spectroscopy of small bodies in the solar system. Jonathan I. Lunine is professor of planetary science and physics at the University of Arizona, and an interdisciplinary scientist on the* Cassini-Huygens *mission. His interests include Saturn's giant moon Titan, the smaller icy moons, and the origin of giant planets and their moons.*

World Watch

by Louis D. Friedman

Washington, DC—The space shuttle's future now dominates space policy news and will shape American space policy for the next few years. Wrapped up in the shuttle's future is the survival of the Hubble Space Telescope, and the entire story highlights the collision between attainable dreams and reality.

The Bush administration's new human space flight policy, initiated last year, explicitly calls for the shuttle's retirement by 2010. If all goes well with the shuttle's return to flight, however, and the shuttle meets its goal of five missions per year for four years, it may be possible to complete the International Space Station (ISS). But "all going well" is far from certain.

NASA projects that 28 flights will be needed to complete the ISS, although some internal studies and statements by NASA officials suggest that 20 flights might be sufficient. The Planetary Society study of this problem, led by now-NASA Administrator Mike Griffin and veteran astronaut Owen Garriott and published last year, concluded that it would take more time and flights than NASA expects: "This appears to be stretching the program too far and, perhaps equally important, extending funding for the shuttle orbiter too far into the next decade, limiting funds available to move into succeeding stages of the exploration initiative."

If the shuttle return to flight goes as planned, then reaching "core complete" and launching the international modules are possible within the 2010 retirement constraint. If there are delays or problems, however, the shuttle's funding requirements will soar and the administration's vision for space exploration will be imperiled.

This brings us to the issue of the Hubble Space Telescope—a political hot potato. Why did NASA feel compelled to announce in 2004 that it would not service the space telescope in 2008, when it is expected to need repair? NASA couldn't know when or exactly what would be needed, and it certainly couldn't know the shuttle's flight status at that time. Instead of diligently studying alternatives to save America's premier astronomical facility, and without consulting the scientific community or the public, NASA peremptorily decided to let Hubble die.

By 2008, it may turn out that a Hubble servicing mission will be just too expensive or dangerous. Conversely, squeezing in one more shuttle flight to save Hubble may then be considered prudent. The decision to give up on Hubble was premature. The Planetary Society is lobbying for Congress to order NASA to take no action now to prevent a servicing mission in the next few years.

Washington, DC—Even more ridiculous than giving up on Hubble prematurely was the announcement that NASA may turn off the *Voyager* probes now racing toward the edge of our solar system, even while they are gathering valuable data. Here, NASA cannot invoke safety, as it is doing with the shuttle, and the amount of money to be saved is very small—millions, not hundreds of millions, of US dollars.

In its 2005 budget, NASA received more money than it expected. Why would it need to shut off productive missions? The sad reason is because it can. In a last-minute deal negotiated by Congressman Tom DeLay (R–TX), previous congressional restrictions to protect science funding were removed and NASA was given freedom to transfer funds out of science into the shuttle and space station programs.

The Planetary Society is fighting to save the *Voyager* mission. The spacecraft are at the edge of the solar system, on the verge of entering interstellar space. Shutting them down is like telling Lewis and Clark not to return home with their discoveries after exploring the American West!

Washington, DC—The Jupiter Icy Moon Orbiter (JIMO) was postponed indefinitely. NASA said the development of nuclear-electric propulsion would take longer and was more complex than it had anticipated when Project Prometheus, for which JIMO was the first mission, was initiated.

The Planetary Society had warned against this possibility. In a position paper two years ago, we supported nuclear power and propulsion for space missions but warned against rushing its development or tying priority missions to its use. With JIMO postponed, we are left with no mission to explore Europa or its putative under-ice ocean.

David Southwood, the European Space Agency's (ESA) science head, has proposed that NASA and ESA investigate an international mission to Europa. We think that is a great idea. Any mission to Europa will require a powerful launch vehicle to reach the Jupiter system. Launch vehicles such as the Russian Proton and the European Ariane could make it possible to include a surface explorer. The Planetary Society urges that a mission to Europa be developed as an international effort.

Louis D. Friedman is executive director of The Planetary Society

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Questions and Answers

Presumably, Titan's white ice "rocks" would sink in liquid methane. Would Titan's low gravity increase their mobility? Would a methane river on Titan be able to easily carry large ice boulders long distances?
—Robert Vint
Totnes, Devon, England

The basic processes of transporting sediment in fluid would likely work more easily on Titan than they do on Earth.

We think the fluid doing the transporting over land on Titan (for example, in rivers) is a mix of methane and nitrogen; in lakes or seas, ethane would also be a part of the mix. Because these mixtures have a lower viscosity than water, they would exert less force on sediment, thereby decreasing its mobility.

However, the sediments being transported on Titan are made of either hydrocarbons or ice, both of which have a lower density than the silicate sediment on Earth. This would increase their mobility. Titan's lower gravity would indeed reduce the weight of the sediment, which would also increase its transportability.

So, all other factors being equal, on Titan the effect of the transporting fluid's lower viscosity would be outweighed by the effect of the moon's lower gravity and the lower density of the sediment.

But not all other factors are necessarily equal. For example, the transportation of sediment in a fluid also depends on the speed of the liquid's flow—faster flow can better carry sediment. Both slope and gravity will affect the velocity of a fluid's flow over land. Titan's lower gravity would reduce a liquid's velocity, thereby reducing fluid sediment transport. Of course, slopes can induce or reduce sediment transport, depending on whether they are steep or flat. The *Cassini* radar altimetry data we have so far show a rather flat landscape, but stereo imaging captured by *Huygens* shows a hill about 100 meters high. We have much more to learn about the topography of Titan before we can tell how its "rivers" or other overland flow phenomena compare to Earth's for transporting sediment.

In lakes, seas, and oceans, the motion of fluid is controlled by currents rather than by movement downhill. Currents on Earth are generally controlled by wind, by tides, and by density gradients in the water. Wind velocity on Titan is likely to be lower than it is on Earth because of Titan's thicker atmosphere, lower solar heating, and more homogeneous heat distribution. Tides there are also modest because Titan is in a tidally locked orbit with Saturn. Density gradients in bodies of water on Titan also are probably low, as a result of wind-mixing and the deposition of heavier organics from above the atmosphere. Thus, fluid flow and sediment transport in lakes, seas, or oceans on Titan could be low as well.

Also, if little sediment is made available through erosional processes, its transportability will be low. Yet another consideration is the difference between sediment transport and sediment entrainment (drawing particles into the fluid before transporting them). Entrainment of particles from the ice bedrock would be much more difficult than their transport in the fluid because they can be partly shielded by surrounding particles.

So, although water ice or organic sediment in hydrocarbon liquid may move more easily on Titan than on Earth, many other factors affect the process. If there is enough topographical slope and sufficient erosion of the ice bedrock (to create sediment in the first place), then rivers (or flash floods) on Titan would likely be able to carry this sediment onto the plains.
—DEVON BURR,
The SETI Institute

If a solar sail were launched to some distant planet or star, how would it slow down once it neared its destination? Could it use the light from another sun to slow it down?
—Steven Shimizu
San Jose, California

Yes, it could use the light from the target star to slow it down. It could also use the light from the laser that was propelling it toward the star. Physicist and science fiction author Robert Forward invented a unique concept for using laser light reflected off a detached portion of a sail to slow down the main spacecraft. This would be done by detaching a portion of the sail, which would result in the larger sail speeding up and getting ahead of the smaller sail. Turning the larger sail to reflect the laser's light at the smaller sail would result in drag that would slow down the main sail.
—LOUIS D. FRIEDMAN,
Project Director

As we know, humans generate electromagnetic signals of various frequencies that then propagate into outer space. These signals lose strength as they recede from Earth until they are lost in the background noise of the universe. At what distance from Earth (in light-years) does this happen to an average-strength radio signal?
—Manos Paradissis
Athens, Greece

That is a good question. Most signals from Earth, such as

television transmissions, could be detected only at a distance of about 1 light-year or less, if the aliens used antennas similar in size to ours.

The strongest signals normally broadcast by Earth are military radar signals. These use powerful transmitters of about 1 megawatt. They focus the signals into a beam, strongly concentrating them in a particular direction. They could be detected farther away.

If the aliens had an antenna that is the same size as our largest antenna (the 300-meter dish at Arecibo, Puerto Rico), then those signals could be detected at about 50 light-years from Earth.

—THOMAS R. McDONOUGH,
SETI Coordinator

Factinos

The massive asteroid belt detected around the star HD 69830 might look like this in the night sky of a hypothetical planet in that system. Although the Spitzer Space Telescope's infrared camera found a great deal of dust, presumably from asteroids crashing into each other, it found no evidence of a planet. However, scientists speculate that one or more planets may be present there.

Illustration: NASA/JPL-Caltech/ R. Hurt, Spitzer Space Center

Scientists using the Spitzer Space Telescope have spotted what may be a dense, dusty asteroid belt circling a star similar to our Sun. The star, called HD 69830, is located 41 light-years from Earth. If it is confirmed, the new asteroid belt would be the first one found around a star about the same age and size as our Sun. Two other similar belts are known, but they orbit stars that are younger and more massive.

Although this new belt is the closest match to our own, it is much thicker, and it contains 25 times as much matter. If our own asteroid belt was this dense, a brilliant band of light reflected from its dust would dominate our night skies.

Charles Beichman of the California Institute of Technology and his colleagues used Spitzer's infrared spectrograph to observe 85 Sun-like stars. Only HD 69830 was found to have a disk of warm dust confined to the inner part of the star's system. The dust most likely came from a belt where the asteroids collide about every 1,000 years.

"Because this belt has more asteroids than ours, collisions are larger and more frequent, which is why Spitzer could detect the belt," said George Rieke of the University of Arizona. "Our present-day solar system is a quieter place, with impacts of the scale that killed the dinosaurs occurring only every 100 million years or so."

—from the California Institute of Technology

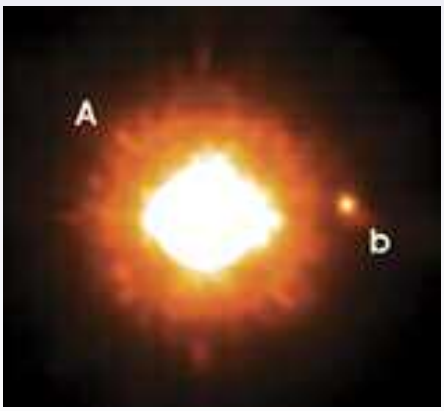
A team of German scientists led by Ralph Neuhäuser of the University of Jena, Germany has released an image of an object orbiting inside the dusty disk around a young star (see image below). The parent star, GQ Lupi, resides in the Lupus 1 cloud, a region of star formation about 450 light-years away.

It is a T-Tauri star, meaning it is very young and lightweight, and has not yet become a main sequence star like our Sun. The substellar object, GQ Lupi b, is located about twice as far from its star as Jupiter is from the Sun, and it takes about 1,200 years to complete a single orbit.

Whether the newly detected companion is ultimately classified as a planet or brown dwarf will depend on its mass. The team currently estimates its mass to be between 1 and 42 times that of Jupiter, but the theoretical models on which they based their estimate are unreliable when applied to such young star systems.

The team used the European Southern Observatory's (ESO) Very Large Telescope atop Cerro Paranal in Chile to make their discovery. A letter detailing their findings will be published in an upcoming issue of *Astronomy and Astrophysics*.

—from The University of Jena and ESO



A possible planet has been detected in orbit around the young star GQ Lupi. Because of GQ Lupi's distance from Earth and the companion object's 1,200-year orbital period, it will be hard to confirm or deny its status as a planet anytime soon.

Image: European Southern Observatory

Society News

Save the Date! "Our Next Age of Exploration"

The Planetary Society is turning 25. Please help us celebrate! Our gala Awards Dinner will usher in "Our Next Age of Exploration." Plan to join us in Los Angeles, California, on Saturday, November 12, 2005 for an evening of fun, great food, and fascinating people.

We'll announce the winner of the Thomas Paine Award for the Advancement of Human Exploration of Mars, which has been awarded in years past to some of Earth's greatest explorers. This year, you'll witness the inauguration of a new award: the Carl Sagan Award for Public Presentation of Science.

Over the past 25 years, The Planetary Society has grown into Earth's largest space interest organization. Our international membership is a force in shaping space exploration. The Planetary Society, with its *Cosmos 1* solar sail, is among the intrepid band of pioneers launching their own private space missions.

This is what we'll celebrate at the "Our Next Age of Exploration" Awards Dinner. As the date approaches, we'll be posting information on our website at *planetary.org* and also in *The Planetary Report*.

If you'd like to know about sponsorship opportunities, please contact Andrea Carroll via e-mail at *andrea.carroll@planetary.org* or at 626-793-5100, extension 214.

—Andrea Carroll, Director of Development

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Planned gifts are enduring gifts. They can bolster projects, operations, and grant and scholarship programs. They can provide crucial funds for unanticipated initiatives. Your memory and legacy are celebrated with your gift to the future of space exploration.

A bequest in your will—of specified amounts of cash, securities, life insurance, real estate, or other property—provides a welcome and much-needed gift to the Society, and it may also enable you to retain current assets and save on estate taxes later.

Please contact Andrea Carroll at 626-793-5100, extension 214 or via e-mail at *andrea.carroll@planetary.org* if you would like to inform us of your estate plans, or if you would like to discuss making a planned gift.

Thank you to all of you who have already so generously included us in your plans.

—AC

Great Comet Crater Contest

The Planetary Society invites you to make your best guess on how big a crater will be created when NASA's *Deep Impact* mission releases an impactor projectile in the path of Comet Tempel 1 on July 4, 2005.

Anyone may enter the Great Comet Crater Contest. Participants may enter online at *planetary.org/deepimpact* or may mail their entries on a postcard to the Great Comet Crater Contest, The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106. Please include the entrant's name, mailing address, e-mail address, phone number, and the guessed diameter (in meters) of the crater. All entries must be received prior to the moment that the impactor strikes Tempel 1, 05:50 GMT on July 4, 2005 (10:50 p.m. PDT on July 3). Only one contest entry per person is allowed.

All entrants who guess within 10 meters of the correct crater diameter will be entered into drawings for three grand prizes—custom-made plaques made of the same kind of copper material that makes up the heavy mass of the impactor, laser-engraved with the *Deep Impact* mission logo. Up to 150 runners-up will receive a certificate and a *Deep Impact* spacecraft paper model.

—Emily Stewart Lakdawalla, Science and Technology Coordinator

Sail to Space with The Planetary Society!

Cosmos 1 is nearly ready to launch. Commemorate this historic project with these Planetary Society–exclusive products:

Cosmos 1 Mission Patch

This 3-inch embroidered patch is the official mission patch for _Cosmos 1_. 1 lb. **#578 $3.50**

Cosmos 1 Mission Pin

Polished silverplate with a vibrant, dark blue enamel background, our official mission pin is 1 inch in diameter.
1 lb. **#579 $5.00**

Cosmos 1 Crystal Cube

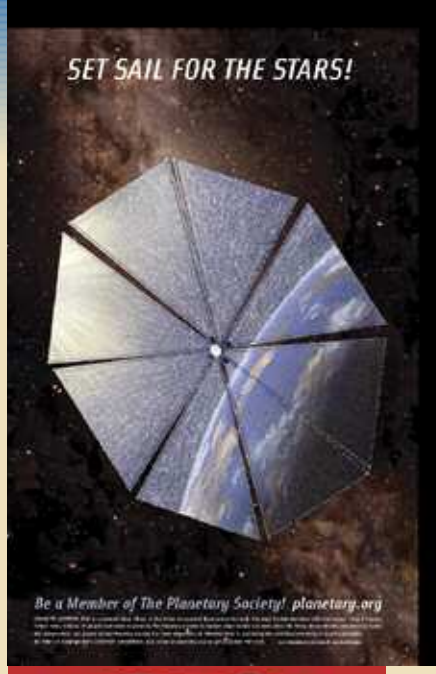
Commemorate _Cosmos 1_'s historic first flight with this stunning laser-etched crystal cube. Our elegant eight-bladed spacecraft floats inside double-beveled leaded crystal with the title "_Cosmos 1_, The First Solar Sail." Each 2-inch cube comes in a satin-lined gift box.
2 lb. **#577 $49.00**

Cosmos 1 Thermal Mug

This stainless steel, 16-ounce thermal mug filled with your favorite hot beverage will help keep you warm on chilly nights of solar sail watching. A limited-edition Planetary Society exclusive.
2 lb. **#575 $18.00**

Set Sail for the Stars! Poster

Cosmos 1 sets sail, leaving its home planet behind. In the distance, the Milky Way beckons. This stunning illustration created by Rick Sternbach captures both the elegance and the promise of solar sailing, the only known technology that may one day take us to the stars. 22" x 34"
1 lb. **#571 $13.50**



Cosmos 1 T-Shirt

The Planetary Society's _Cosmos 1_, the first-ever solar sail, will take off into orbit this year. This commemorative T-shirt is a Society exclusive. Long-sleeved, with glow-in-the-dark ink, it's perfect for dark nights of solar sail watching.
Adult sizes: S, M, L, XL, XXL
1 lb. **#570 $25.00**

Cosmos 1 Team Jacket

Planetary Society Members are an essential part of the _Cosmos 1_ team! Get your official team jacket only through The Planetary Society. These water-resistant jackets are cobalt blue with "_Cosmos 1_ Team" embroidered on the front and logos for The Planetary Society, Cosmos Studios, and Russian space agencies printed on the back. Special order only (allow 6–8 weeks for delivery).
Adult sizes: M, L, XL
1 lb. **#573 $60.00**

Order Today!

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or 1-626-793-5528 (International)
Shop online at The Planetary Store: _http://planetary.org_

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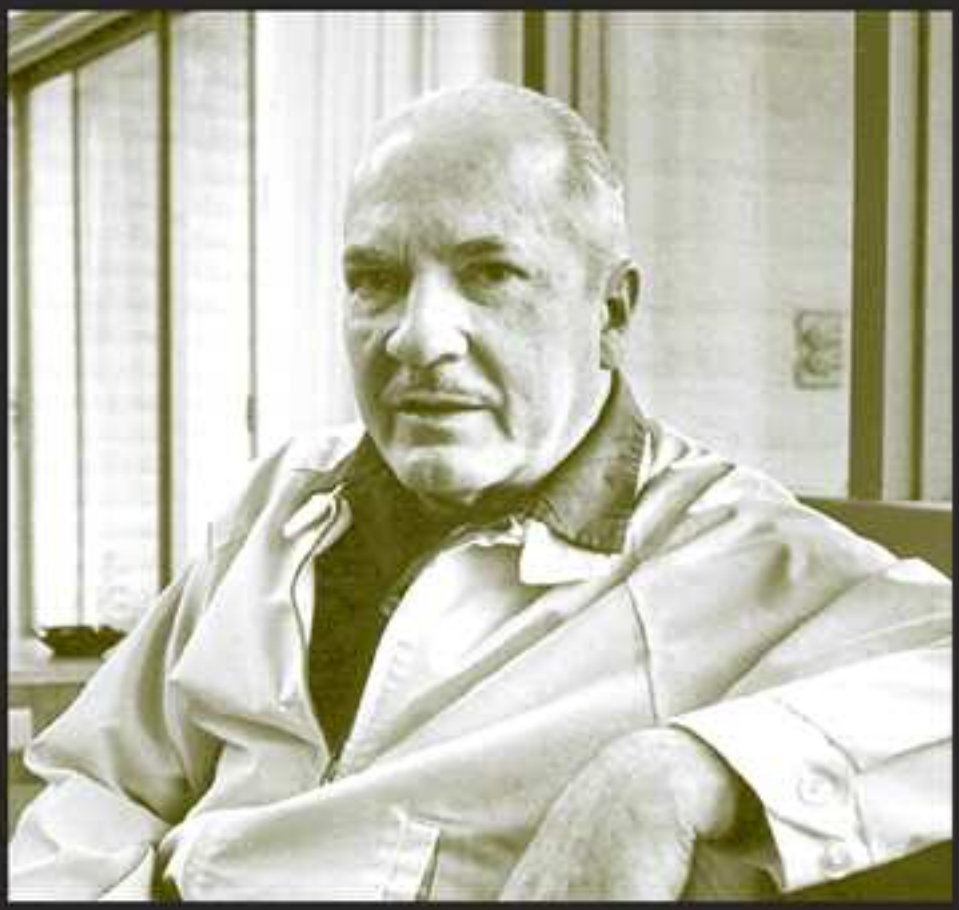
Marketplace

The Trustees of the Robert A. and Virginia Heinlein Prize Trust are pleased to announce the selection of

Meisha Merlin Publishing, Inc. as publishers of the complete works of Robert A. Heinlein.

The Virginia Edition will be available by limited subscription later this year as a set of 46 hardbound slipcased volumes.



For information about the Virginia Edition please see:
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For information about the Heinlein Prize Trust please see:
www.heinleinprize.com

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