The PLANETARY REPORT

Volume XXVIII Number 1 January/February 2008

Jupiter's Changing Face

From The Editor

It's a presidential election year in the United States and, as politics engulf us, it's hard to ignore one prickly fact about space exploration: it's inherently political. No matter how much we talk about the great adventure and inspiration of space, as space science is done in the United States, it's a political endeavor.

As I write, the governments that fund the European Space Agency are uncertain if they want to commit to a human space program, and an ESA committee is deciding which robotic missions the agency can afford to start.

The Chinese, Indian, and Japanese governments have targeted the Moon to demonstrate their technical and scientific prowess. The Russian government is ramping up its space program, and nations from Brazil to Iran are building space capability.

The new commercial rocket companies are barely off the ground, and even for them, governments are the biggest customers. The first space tourists have yet to fly, and when they do, the flights will be government regulated.

There's no escaping it: we can't avoid dealing with governments and politics.

That brings us to influencing the political process. The Planetary Society exists in part to make the public's voice heard by politicians. The Save Our Science! campaign succeeded in swaying the U.S. Congress to support planetary exploration, and judging from the administration's 2009 budget, that government branch also listened.

But budget season has just started. In an election year, things can get wacky. We have to be vigilant; we have to keep pushing. We have to work together in The Planetary Society.

—Charlene M. Anderson

On the Cover:

This view of the tumultuous region just left of Jupiter's Great Red Spot is a cropped and enlarged portion of the most detailed global color portrait ever produced of the giant planet. *Cassini* took the images that constitute the global mosaic on December 29, 2000, during its closest approach—a distance of about 10 million kilometers (6.2 million miles). Although *Cassini*'s camera can see more colors than humans can, the colors in this view are very similar to what our own eyes would see. Image: NASA/JPL/Space Science Institute

Background:

This global map of Saturn's moon Iapetus, created using *Cassini* and *Voyager* data, was released in December 2005. The map is an equidistant projection and has a scale of 641 meters (2,103 feet) per pixel. Some of the territory visible here was imaged by *Cassini* using reflected light from Saturn, or "Saturnshine."

Map: NASA/JPL/Space Science Institute

Contact Us

Mailing Address: The Planetary Society,
65 North Catalina Avenue, Pasadena, CA 91106-2301

General Calls: 626-793-5100
Sales Calls Only: 626-793-1675
E-mail: *tps@planetary.org*
World Wide Web: *http://planetary.org*

Contents

The Planetary Report (ISSN 0736-3680) is published bimonthly at the editorial offices of The Planetary Society, 65 North Catalina Avenue, Pasadena CA 91106-2301, 626-793-5100. It is available to members of The Planetary Society. Annual dues in the United States are $30 (U.S. dollars); in Canada, $40 (Canadian dollars). Dues in other countries are $45 (U.S. dollars). Printed in USA. Third-class postage at Pasadena, California, and at an additional mailing office. Canada Post Agreement Number 87424.

Editor, CHARLENE M. ANDERSON
Associate Editor, DONNA ESCANDON STEVENS
Managing Editor, JENNIFER VAUGHN
Technical Editor, JAMES D. BURKE
Copy Editor, A. J. SOBCZAK
Proofreader, LOIS SMITH
Art Director, BARBARA S. SMITH
Science Editor, BRUCE BETTS

A PUBLICATION OF THE PLANETARY SOCIETY

Global Upheaval on Jupiter: Change Is Good!

by Amy Simon-Miller

Everything visible on Jupiter is a cloud—and recently these clouds have been changing their stripes. A year ago, New Horizons *swung past Jupiter on its way to Pluto and tested its instruments on the gas giant. This picture, taken along the planet's terminator—or boundary between day and night—reveals massive global changes in storm activity and the colors of Jupiter's iconic atmospheric bands. If this image creates a feeling of déjà vu, it's because we love it so much we had to use it again—and wanted to really show it off with an enlarged version. For a detailed caption, see "2007—The Year in Pictures" in the November/December 2007 issue of* The Planetary Report, *or on our website at* planetary.org.
Image: NASA/JPL/Southwest Research Institute (SwRI)

Although violent weather changes on Earth are not usually a good thing, for Jupiter scientists, change is good! In 2007, Jupiter put on a colorful show of rapidly changing cloud bands, which created an overall appearance very different from what had been seen over the past decade.

Movies and images of the planet show ever-changing, swirling, turbulent clouds alongside storm systems, some of which last a very long time, like the Great Red Spot. How can stable storm systems exist amid all this apparent turbulence? What causes the planet's alternating bands of white and colored clouds to change color on short time scales? What does this tell us about the parts of Jupiter we cannot observe directly?

The flurry of recent Jovian cloud activity, captured by spacecraft and ground-based telescopes, will allow us to investigate these questions better than ever before. The data will give us a chance to learn much more about Jupiter.

Early Views of the Gas Giant

Jupiter—the largest planet in the solar system—is easy to observe from Earth at night during the portion of the year when it is not blocked by the Sun. It was first recognized by the ancients as a bright point of light systematically moving against the background stars. With the invention of the telescope, people could observe colors, cloud features, and storms on the planet. Historical reports on these aspects of Jupiter's appearance span centuries, first as written accounts and sketches and later with permanent photographic records.

These reports vary in accuracy and reliability, but they still provide an interesting history of the planet and of our early insight into its planetary dynamics. Past records include measurements of Jupiter's rotation rate and the relative drifts of large cloud features.

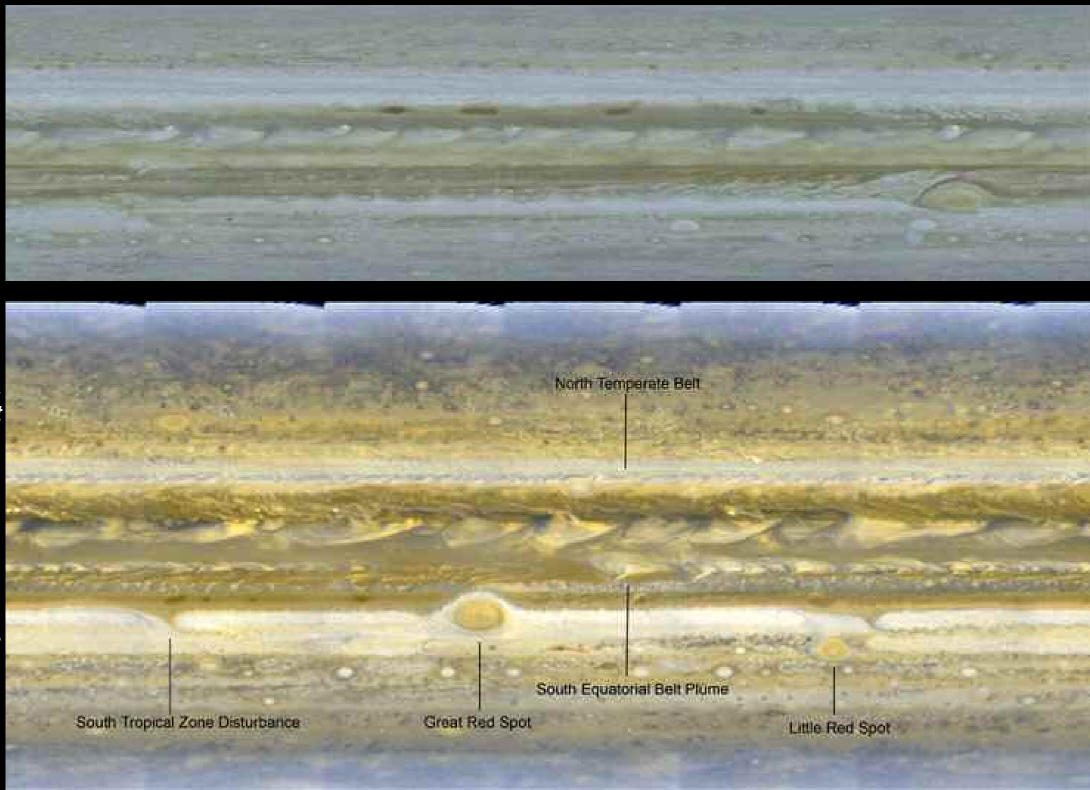
The reports also include many accounts of the numbers, sizes, locations, and interactions of "spots," or large storms, particularly after the mid-1800s, including tracking reports on the Great Red Spot. Though such big spots were occasionally reported as early as the mid-1600s, the sparse records don't allow tracking of a single storm's existence that far back. From the mid-1800s to the present, however, we do have detailed accounts of the color of storms and cloud bands on Jupiter.

Reports of color are highly subjective. For example, in written accounts, the Great Red Spot (GRS) has been described with various colors, including salmon, brick, tawny, and copper. The same variety of description has occurred for Jupiter's belts (darker cloud bands) and zones (white cloud bands). Although the actual color is subject to interpretation, reports of large changes in color within a single region probably are more reliable, as they are comparisons with other nearby regions. The best-recorded episodes were reported by multiple independent observers, and in some cases, recordings included photographic plates.

Watching the Clouds

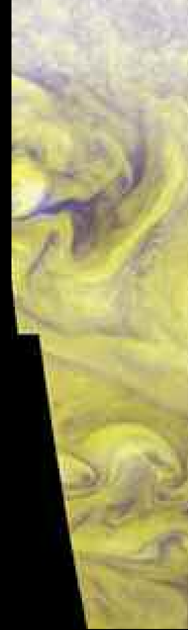
The modern observational era was ushered in with the first flyby of a spacecraft and with the advent of CCD

Three spacecraft captured these views of Jupiter over a span of 27 years. At left is a **Pioneer 10** *photo from December 1973,* **Voyager 1** *took the center shot in January 1979, and at right is* **Cassini**'*s mosaic from December 2000. Although the colors (particularly "redness") of these globes vary due to the spacecrafts' different cameras and filters, changes at the planet's equator and the area near the Great Red Spot still shine through.* Images: NASA/JPL/Space Science Institute



To complement the data New Horizons *would gather at Jupiter in February 2007, scientists made many ground-based and Hubble Space Telescope (HST) observations. These coordinated observations captured detailed evidence of unexpected changes at many latitudes on Jupiter. The changes are apparent in these cylindrical "snakeskin" maps of Jupiter from* Voyager 1 *(February 1979) at top and from HST (February 2007) below. Both maps approximately circle the globe—they each span roughly 360 degrees (plus or minus 20 degrees) of longitude.*

Images: NASA/JPL/ESA



(charge-coupled device) technology and modern instruments. These advances offered even sharper views of Jupiter while adding to our historical record and allowing new interpretations of some past observations.

First, scientists confirmed Jupiter's internal rotation rate through its radio emissions. Because Jupiter's magnetic field is tilted relative to its rotation axis, the signal that it generates acts as a planetary lighthouse, sweeping across our line of sight. This enables an accurate determination of the rotation rate.

Next, high-resolution images allowed scientists to track individual small cloud features. This led to the calculation of an average wind profile, relative to the rotation rate, at most latitudes. This profile showed an alternating pattern of high-speed eastward and westward wind jets that reached speeds of nearly 650 kilometers (400 miles) per hour at some locations. Spacecraft observations confirmed that these average winds change very little over time, a big surprise to atmospheric scientists. On Earth, this would be like saying "Because I live at 40 degrees north latitude, my winds today will be 40 miles per hour from the east, just like yesterday, last week, and last year."

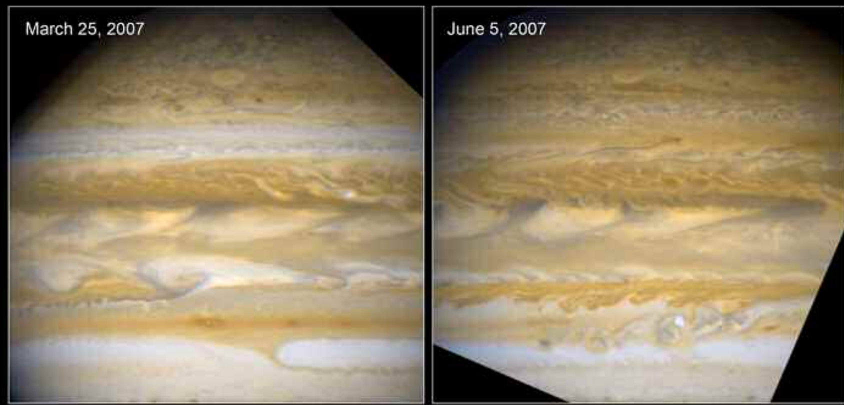
At first glance, Jupiter's winds appear to be related to the belts and zones. The wind pattern is somewhat aligned with the colored belts and white zones, with the highest east and west wind speeds (up to 500–650 kilometers/300–400 miles per hour) usually occurring along those color boundaries.

Many scientists suggest that the alternating cloud colors are due to Jupiter's fast rotation and alternating wind jets. Those clouds can change color on relatively short time scales, however, whereas the winds do not change much at all. If cloud color were truly tied to rising and sinking air, the winds in the affected area would have to reverse directions in conjunction with color changes—something we have not observed. For instance, we can compare Jupiter's varied appearance from *Pioneer 10* (December 1973), *Voyager 1* (January 1979), and *Cassini* (December 2000), all of which found similar average wind profiles despite regional color differences.

In addition to the confusing connection to cloud color, the Jovian wind jets seem to constrain large storms. For instance, the wind jets prevent the Great Red Spot from moving to a new latitude but allow it to drift in longitude, although more slowly than storm systems on Earth. At the same time, the winds are deflected around the spot, like a stream flowing around an island. In the case of the GRS, the winds and the large storm have some sort of symbiotic relationship that allows the storm to survive without changing the nearby wind speeds.

In the latitude band south of the GRS, three large white storms were observed to form in the late 1930s. The storms reacted to the winds in a manner similar to the GRS, but in 1998 and 2000, the following storms overtook the lead storm, and they merged to form first two storms, then a single storm. This remaining storm turned red in late 2005, becoming what is now often called the Little Red Spot. Unfortunately, the majority of these events occurred while Jupiter was close to or behind the Sun as seen from Earth, so full observation of the events was not possible.

In the band just south of the Great Red Spot lies a relatively new storm, often called the Little Red Spot, that is roughly 70 percent the size of Earth. It started as three smaller white storms, first seen in the 1930s, that merged into one storm, which then turned red in late 2005. Scientists speculate that a surge of exotic compounds, in particular sulfur-bearing cloud droplets, might have been propelled from below up into Jupiter's high-level ammonia clouds, where they reacted with sunlight to turn the storm red. This color portrait is composed of high-resolution images from New Horizons *and color images taken nearly simultaneously by HST on February 27, 2007.*
Image: NASA/Johns Hopkins University Applied Physics Laboratory/SwRI



These HST views of Jupiter display the significant atmospheric changes that took place north and south of Jupiter's equator between late March and early June of 2007. *Images: NASA, ESA*

Monitoring Change

A complex system of satellites and ground stations monitors Earth's weather every day in many ways, feeding these data into complicated prediction models. We do not have that type of extensive monitoring network on Jupiter, so we must rely on the snapshots of information from spacecraft and telescopes, even though they do not present a complete picture.

From remote viewing data, planetary scientists attempt to figure out what happens in between the limited periods of coverage as well as below the visible clouds, where we cannot see at all. Fortunately, spacecraft missions traveling to the outer solar system often fly past Jupiter to use the giant planet's gravity as an energy boost. This technique has given us extra opportunities for close-up views with advanced science instruments.

The *New Horizons* flyby in late February 2007 is the most recent example. *New Horizons*, which is on its way to Pluto, used a suite of instruments to observe Jupiter for several months. During the same period, many ground-based telescopes and the Hubble Space Telescope (HST) also observed Jupiter. As luck would have it, these observing campaigns recorded with unprecedented detail a series of unexpected changes at many latitudes on Jupiter.

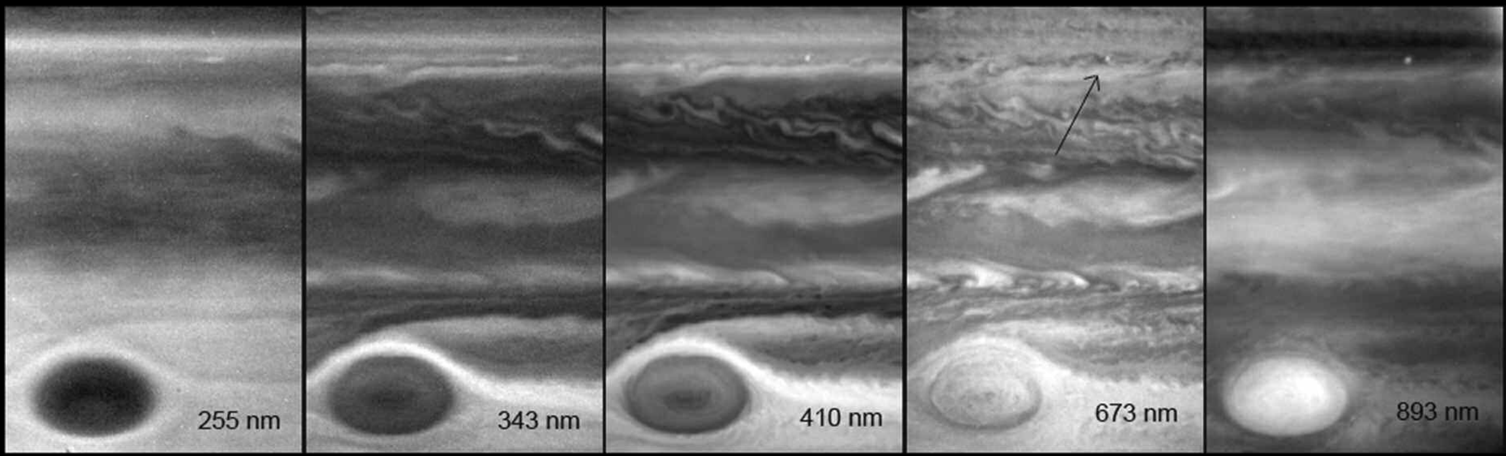
The Global Upheaval of 2007

When multiple belts and zones undergo change somewhat close in time, planetary scientists often refer to the event as a *global upheaval*. Despite the name, that doesn't mean the entire planet undergoes change at exactly the same time. Instead, often a series of changes occur, sometimes rapid and short-lived, other times spaced out and lasting several years.

The global upheaval of 2007 began while Jupiter was not visible to Earth-based telescopes. When ground-based telescopes first could see Jupiter in January, observers noticed that the planet's equatorial region was reddish/brownish, much as it looked during the *Pioneer* and *Voyager* flybys. This was an obvious and dramatic change, because in the mid-1990s and early 2000s—as observed by the HST, the *Galileo* orbiter, and the *Cassini* spacecraft—this region was filled with white clouds.

Other aspects of Jupiter were also reminiscent of the mid- to late 1970s. The southern half of the equatorial region showed increased activity, with large white plumes that seemed to decrease away from a single location. In 2007, there were two reddish cloud projections into the south tropical region, which are associated with the equatorial changes but also represent a disturbance to the wind jet flows in this region. The normally turbulent region west of the GRS was quiet, further indicating a change of flow or rate of upward convection in the region. All in all, Jupiter looked different from its appearance during the previous year, but the changes were far from over.

Toward the end of the 2007 observing campaign in late March, HST observed two tiny white spots at northern temperate latitudes, also where the highest-speed eastward wind jet sits. A few days later, ground-based observers reported a major outbreak at this location, with bright white plumes rising up, spreading out, and encircling the planet within a few Earth days. The event ended in mid-May, with the entire region now dark in color.



At least 10 episodes of global upheaval on Jupiter have been observed since the 1800s. The 2007 upheaval is unique in that for the first time, spacecraft have tracked these changes thoroughly—on a global scale, and with relatively frequent coverage at different wavelengths. These HST maps from March 27, 2007 show the planet's equatorial zone and Great Red Spot in wavelengths from ultraviolet (255 and 343 nanometer, or nm) through near infrared (893 nm). Human eyes are sensitive to light from about 400 to 650 nm. The precursor plume for the upheaval in the North Temperate Belt (see the arrow in the 673 nm frame) is visible at all wavelengths.
Images: NASA, ESA

Observations from HST obtained in early June, as a final attempt to monitor the region, serendipitously caught an outbreak of activity in the southern tropics as well. Over this entire period, the equator remained reddish in color.

Looking Ahead

There is no predicting how Jupiter will look after it emerges from behind the Sun in 2008, nor do we yet fully understand the events of 2007.

The historical record gives some indication of the frequency of these events and which regions are usually involved. From the late 1800s through the present, there have been at least 10 episodes of global upheaval, with the most recent previous event occurring in 1990–1992. There is no obvious spacing to such events, which can happen a few years, or multiple decades, apart. In addition, individual regions much more frequently experience activity not associated with a global upheaval, but also with uneven time spacing. No clear trend has yet emerged that predicts when a region will become active or change color, or if an event at one location will begin a series of changes tied to a global upheaval.

The 2007 upheaval is unique in one respect, however. For the first time, spacecraft data have tracked activity changes on a global scale and with relatively frequent coverage, including ultraviolet, visible, and near-infrared imaging. Intensive ground-based campaigns filled in the time coverage and also included thermal infrared observations.

The multiple wavelength coverage will be particularly instructive. The ultraviolet data give information about the upper atmosphere, including any new cloud features that correspond to these events. The visible images show the colors of the clouds and changes in wind flows. Near-infrared data can discern cloud heights and some composition. Finally, thermal infrared data show areas where heat flow from the interior has changed, usually because of variations in overlying cloud thickness.

In the end, all the observational data will be used in computer models of the circulation on Jupiter. These models are similar to weather models of Earth, except that on Jupiter, we know there is no underlying planetary crust. However, we know little else about conditions below the cloud tops, beyond the hour or so of data provided by the *Galileo* probe in 1995. Nevertheless, trying to match observed events with these simple models can give us insights about Jupiter's interior circulation, because the ways the clouds appear, interact, and evolve over time limit the possibilities for what the environment may be like below the clouds.

The global upheaval of 2007 was far from over by the end of the year, though the equatorial belt appeared to be losing some of its color starting in September. With Jupiter inching even closer to the Sun in the sky, observing ended for a while. Observers eagerly await Jupiter's reappearance in early 2008—with views improving until July's solar opposition—to see what has changed during the hiatus. In addition, Jupiter's largest storms will again pass each other in 2008, so surprises could develop at any time.

Jupiter is always a dynamic world of fascinating and mysterious contrasts. Changes in the clouds of Jupiter are magnificent events, and scientists will continue to use them to uncover what secrets they can tell us!

Amy Simon-Miller is an astrophysicist at the NASA Goddard Space Flight Center. She has studied Jupiter's atmosphere for nearly 15 years, using data from the Voyager, Galileo, Cassini, *and* New Horizons *spacecraft, as well as the Hubble Space Telescope and ground-based facilities.*

Titan's North Polar Seas

by Emily Stewart Lakdawalla

Our November/December 2007 issue had an error on pages 16 and 17 in Emily Lakdawalla's "2007—The Year in Pictures." We published the wrong image of Titan to accompany the caption "Titan's North Polar Seas." Here we showcase the correct image with the author's detailed description of this significant 2007 discovery.
—Jennifer Vaughn, Managing Editor

This year, at long last, *Cassini* found bodies of liquid methane and ethane hiding at Titan's poles. In the decades since methane was detected in the moon's smoggy atmosphere, scientists have suspected the presence of liquid methane on Titan's surface. Any methane in Titan's atmosphere should be destroyed over geologically short periods of a few million years, so its presence means either that we are seeing Titan at an unusual time in its history or that there is a reservoir of methane at and below the surface that replenishes the atmospheric supply.

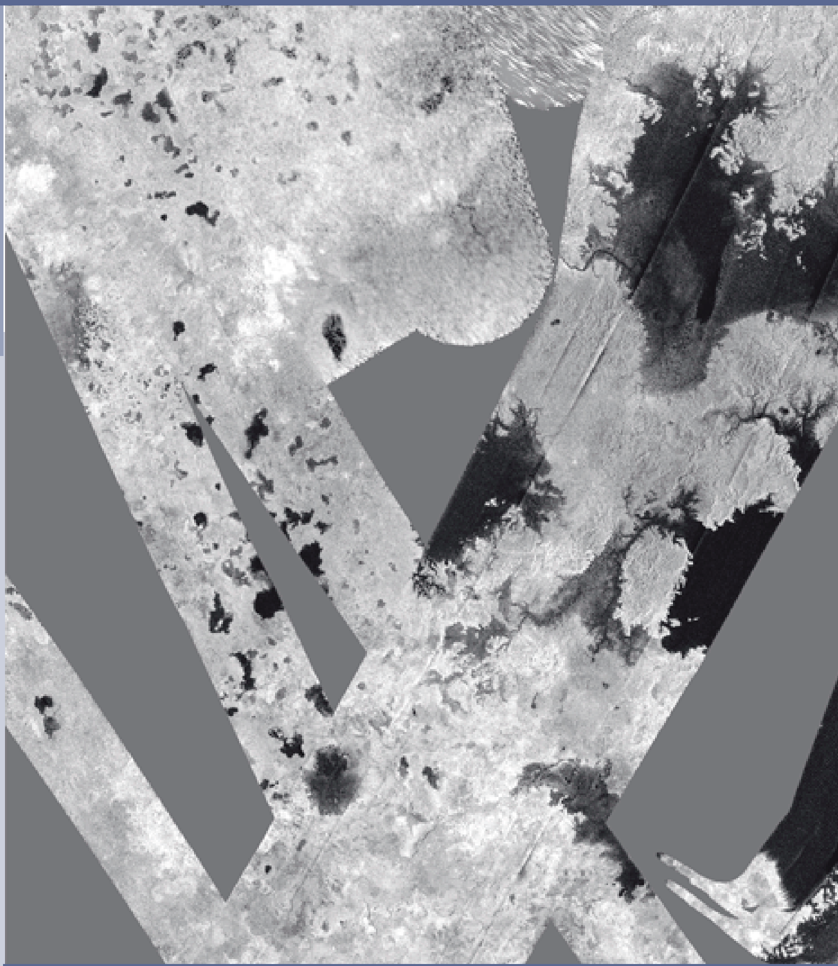
Cassini arrived at Saturn in 2004 with a suite of a dozen instruments, a few of which could penetrate Titan's clouds in infrared or radio wavelengths to see the surface. Throughout the first two years of the mission, no observations were made of areas that without question were liquid-filled seas. Finally, during the summer of 2006, *Cassini*'s navigators began to fly the spacecraft above Titan's north pole in maneuvers designed to increase the spacecraft's orbital inclination. This maneuvering had the collateral benefit of allowing *Cassini*'s radar instrument to gather many thin swaths of images near Titan's north pole through a technique known as synthetic aperture radar (SAR).

SAR images are in black and white, and the brightness depends in large part on the roughness of the surface and local topography. Surfaces that are rough on centimeter-size scales, as well as slopes facing the spacecraft, will be bright, whereas surfaces that are very smooth, as well as slopes facing away from the spacecraft, will be dark.

The north polar SAR swaths instantly bore fruit, revealing the darkest surfaces yet seen on Titan, in circular to irregularly shaped depressions, many of which were clearly fed and/or emptied by sinuous, branching channels. Many other similarly shaped features were not quite so dark. Perhaps the darkest features are currently liquid-filled, and the less dark ones are dry. In some areas, dark features grade to a slightly lighter toned shore. Here, it is possible that *Cassini*'s broadcast radio waves are penetrating the shallowest parts of the seas to reflect from a rougher bottom, or even that the near-shore surface of the sea is roughened by Titanian breezes.

Polar passes continued through 2006 and 2007. Up to the time that this image was assembled in October 2007, the radar team had acquired SAR swaths at a variety of resolutions covering 60 percent of Titan's north polar region above 60 degrees north latitude. About 14 percent of the mapped region is covered by what are interpreted as liquid hydrocarbon lakes numbering more than 400 in various sizes. Most of the lake area is dominated by a few large "seas."

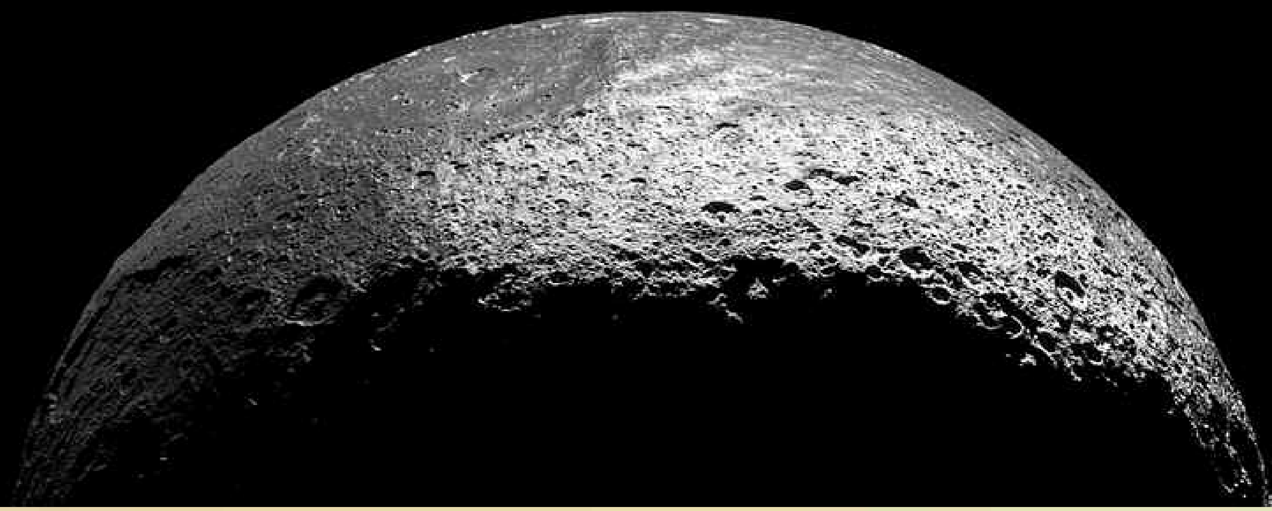
Cassini has now moved on to an orbit that crosses Titan's south pole. Two south polar radar swaths have revealed only a few lakes, in stark contrast to the north pole. Lakes may be a seasonal phenomenon on Titan, expanding during the dark polar winter and vanishing during the long sunlit summer.



In this segment of the July 22, 2006 radar swath on Titan, very dark features are possible lakes; some of the less dark features could be lakebeds that are now dried up. The darkest lake-like feature near the top of this image appears to have a thin drainage channel emptying into it from the east. It may even be possible that this channel connects the lake feature to one of the possibly dried-up features to its southeast. The channel disappears into the background noise of the radar data, however, so evidence that the two features are connected is not conclusive. Image: NASA/JPL

Emily Stewart Lakdawalla is science and technology coordinator for The Planetary Society. She maintains the Society's blog at planetary.org/blog.

Cassini at Iapetus: A Bumpy but Successful Flyby



by Tilmann Denk

Monday, September 10, 2007, was a special date for space exploration: on that day, the *Cassini-Huygens* mission performed its first and only targeted flyby of Saturn's unique moon Iapetus. With a closest approach of only 1,620 kilometers (970 miles), the *Cassini* spacecraft came to within about two radii of the moon.

Accomplishing this complicated feat was a challenge for all parties involved in directing the spacecraft. Orbiting at an average distance of 3.56 million kilometers (2.14 million miles) from Saturn, Iapetus is relatively far from the planet and is outside *Cassini*'s orbit for most of the mission's duration. Iapetus's orbit, furthermore, is currently inclined 15 degrees relative to Saturn's equatorial plane, where the rings and all the other regular satellites reside. Reaching such an object while remaining on a Titan-return trajectory is a difficult and tricky task.

Why Iapetus?

Investigating Iapetus is among *Cassini*'s most important scientific goals. This unusual moon is important because it harbors what might be the oldest unresolved mystery of planetary science: why is Iapetus' leading side (the side that faces in the direction of its orbital motion) dark while the trailing side (the side facing away from the direction of motion) is bright?

Jean-Dominique Cassini, the discoverer of Iapetus, first spotted this moon more than 300 years ago, in the fall of 1671. In 1672, he had to "rediscover" it after an extensive search because he couldn't find it at the pre-calculated position. (Cassini discovered Saturn's moon Rhea as a by-product of that search.) After finding Iapetus again, Cassini realized why he had so much trouble: he could see this moon only on the right side of Saturn but not on the left side. He correctly claimed that Iapetus must be in synchronous rotation, and that one hemisphere (the leading side) is much darker than the other.

Cassini probably did not consider trying to find an explanation for this unusual dichotomy in brightness. The first serious attempt came nearly 300 years after Cassini's discovery. Harvard-Smithsonian scientists Allan F. Cook and Fred A. Franklin, in an article that appeared in the journal *Icarus*, suggested that Iapetus had been covered by a layer of thin, bright, icy material, but impacts by "micro-meteorites" had erased this feature on the moon's leading side.

Since the publication of Cook and Franklin's paper, multiple other hypotheses have been developed. In particular, images from the *Voyager* spacecraft showing the northern side of Iapetus on the side opposite from Saturn at a resolution of about 9 kilometers (5 miles) per pixel and the Saturn-facing side at a resolution of about 20 kilometers (12 miles) per pixel inspired myriad imaginative suggestions from researchers. None of these proposals, however, has satisfied the majority of planetary scientists.

Considering all this, it is not surprising that the investigation of Iapetus has remained a top priority for a Saturn-orbiting spacecraft. Nevertheless, when mission planners realized how difficult it would be for the *Cassini* spacecraft to reach Iapetus, they limited their plans to only a single targeted flyby of this moon during the four years of the spacecraft's primary mission. *Cassini*'s orbital trajectory had been more or less fixed in 2000, and since that time, we have known that the close encounter with Iapetus would occur, if all went well, on September 10, 2007. The spacecraft would approach the moon from its

Saturn's far-flung moon Iapetus is unique among solar system bodies for its stark black-and-white visage. Although Cassini*'s path to Iapetus often resembled an obstacle course, the close scrutiny of this odd, yin/yang world was one of the spacecraft's most important goals. It achieved that goal beautifully. This mosaic of Iapetus is constructed of images captured by* Cassini *on the morning of January 1, 2005 from a distance of 140,000 kilometers (87,000 miles).* Image: NASA/JPL/Space Science Institute

unlit leading side and depart from the illuminated trailing side, with its closest approach taking place at a low latitude over the anti-Saturn hemisphere.

Planning the Encounter

Once the timing and trajectory of the flyby were set, *Cassini*'s Satellite Orbiter Science Team (SOST) began to negotiate how to distribute the time near closest approach among the various instruments on the spacecraft. SOST includes representatives from the science groups of each of *Cassini*'s instruments. Working through regular telephone conferences, the team is responsible for preparing the observation strategies, timelines, and spacecraft attitudes for all satellite flybys.

In 2000, three competing requests were on the table: optical remote sensing (ORS) of the surface, in-situ measurements by the fields-and-particles instruments such as the cosmic dust analyzer or the magnetometer, and an observation of a stellar occultation—a geometry in which Iapetus blocks out the light of a known star in the background. This last option would use *Cassini*'s Ultraviolet Imaging Spectrograph (UVIS) instrument to help determine whether Iapetus possesses a (very) thin atmosphere.

In the end, SOST decided to proceed with the UVIS stellar occultation experiment, but with a star that would have been occulted while the spacecraft was "inbound"; before closest approach to the moon, when only the crescent would have been visible. The star Zeta Ophiuchi was in the right position and best suited for conducting the experiment. A few minutes after closest approach, the ORS instruments were to take over and begin collecting high-resolution data from the surface. Unfortunately, the requirements of these two experiments were incompatible with the spacecraft attitudes required by the fields-and-particles instruments, and SOST decided that they would not get their preferred spacecraft attitude.

Even so, without taking the requirements of the fields-and-particles instruments into account, certain issues were left unresolved temporarily, including the crucial question of how the spacecraft could return from inertial stellar pointing back to surface tracking within the required short amount of time.

As the person responsible for imaging observation planning of Iapetus on behalf of the *Cassini* imaging team, I was not at all happy with this compromise, because the UVIS stellar occultation was to take place just before closest approach. This would exclude the possibility of ISS (Imaging Sub-System) observations of the dark terrain at very high spatial resolution during the spacecraft's approach to the moon. In particular, we wouldn't be able to observe the Voyager Mountains rising above the horizon with this plan. Nevertheless, I was comforted by the knowledge that the orbit of Iapetus was not known well enough for detailed planning and by the hope that things might improve when the time came for the final flyby preparations.

The Quest for the Voyager Mountains

The informally named Voyager Mountains are several huge, isolated mountains near Iapetus' equator on its anti-Saturn side. They were discovered by our group in 1999 in *Voyager 2* data, where they show up nicely at the horizon. We estimated that they were more than 20 kilometers (12 miles) high, keeping in mind the huge margin of error when using images with resolution of nine kilometers (about six miles) per pixel. Initially, we had no really useful ideas of how the mountains had formed, but this changed on Christmas Day of 2004.

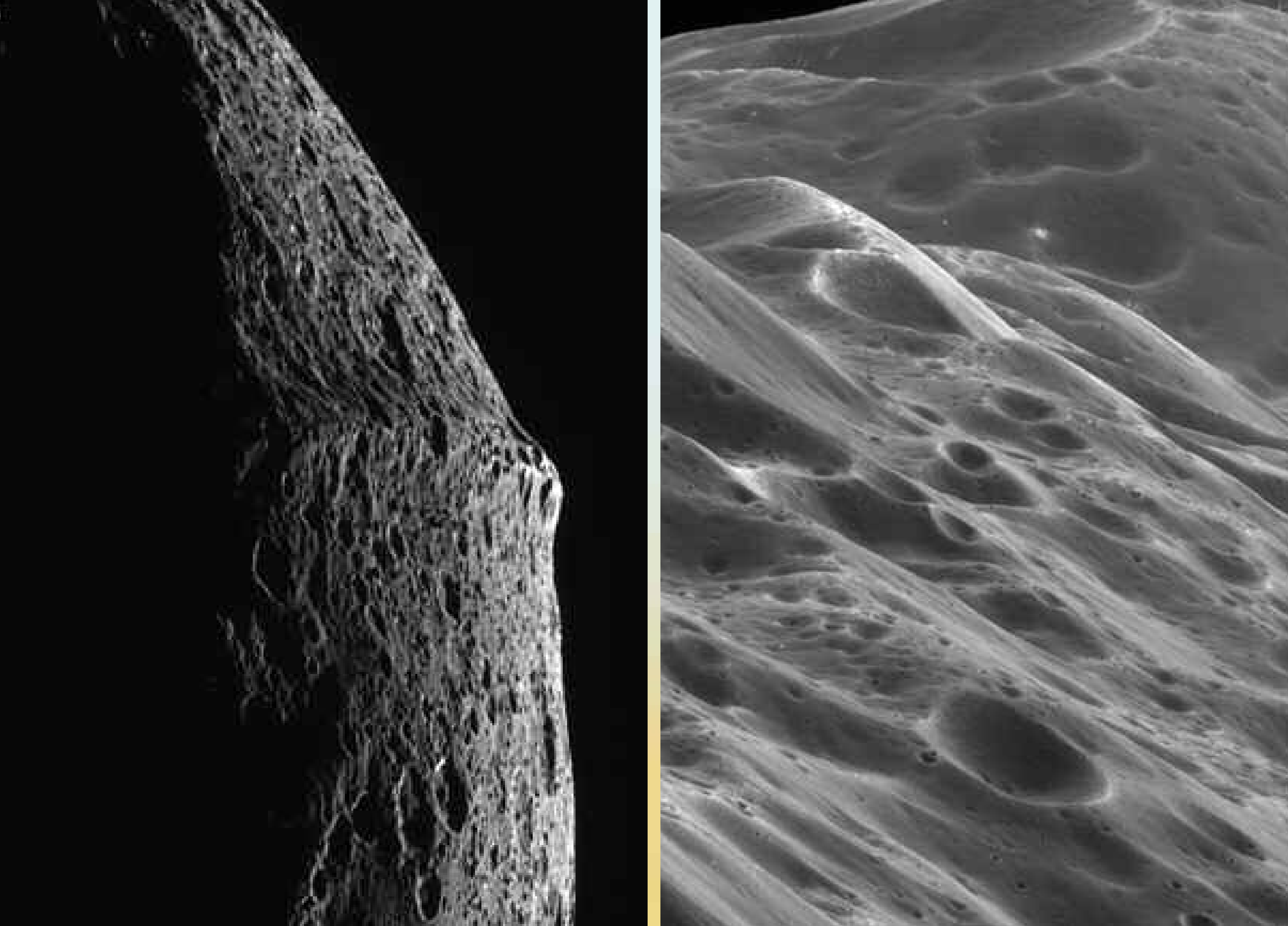
On December 25, *Cassini* took images of the leading side of the moon at a resolution of six kilometers (four miles) per pixel, which showed a faint linear streak running exactly along the equator, including a very pronounced bump at the western limb that was about 20 kilometers (12 miles) high. It now became apparent that the Voyager Mountains are part of a much larger equatorial ridge or chain of mountains that spans at least one third to one half of Iapetus' circumference.

This discovery took place just seven days before the so-called B/C flyby of Iapetus, when *Cassini* passed within 124,000 kilometers (74,000 miles) of the moon. This gave us one week of pleasant anticipation, because we knew that we would get spectacular images of the ridge at a resolution better than one kilometer per pixel.

The B/C flyby is so named because it took place near the apoapsis—the position farthest away from Saturn—at the end of orbit B and the beginning of orbit C. After the targeted flyby, the B/C flyby remains the second best of Iapetus and was by far the closest approach at the time.

The story of this unexpected flyby would warrant an

The first serious attempts to explain Iapetus' two-faced nature would not occur until more than 300 years after the moon's discovery in 1671. Voyager*'s groundbreaking images of Iapetus inspired many theories, but none has gained acceptance by most planetary scientists.* Voyager 2*'s closest approach to the satellite was 966,000 kilometers (600,000 miles). It took this picture of Iapetus on August 22, 1981.* Image: NASA/JPL

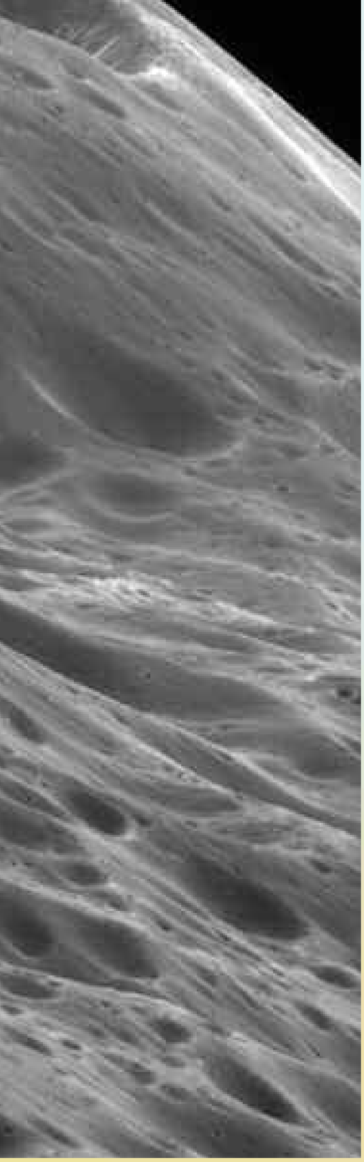


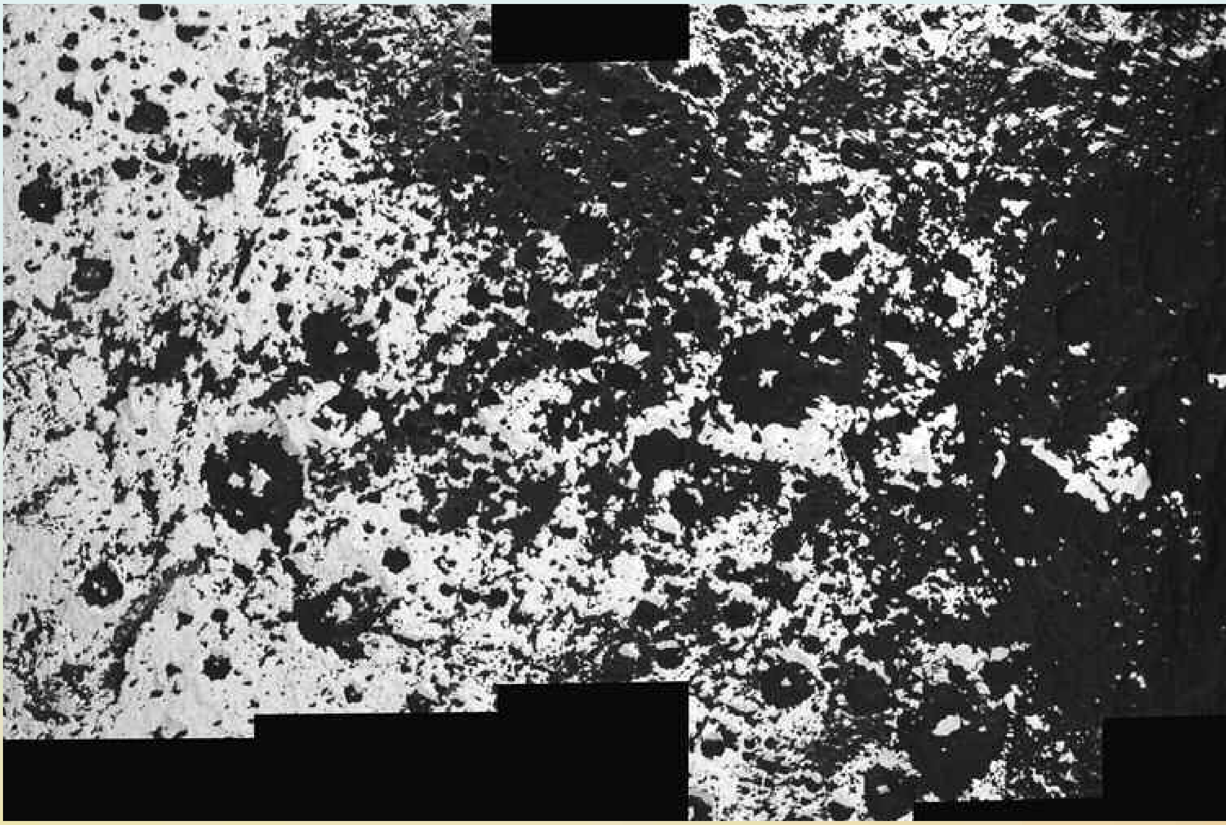
On Christmas Day of 2004, Cassini *imaged a feature that added to Iapetus' mystique—a mountainous, equatorial ridge that circled one third to one half of the moon's diameter. The feature was quickly nicknamed "the Belly Band." It would be almost three years before* Cassini *could return to take a closer look. Above left: This raw, unprocessed image is one of the many that* Cassini *captured during its close approach on September 10, 2007. It was taken by the spacecraft's narrow-angle camera from a distance of about 77,000 kilometers (48,000 miles). Above right: Later that day,* Cassini *swooped in to take this shot from a distance of about 3,870 kilometers (2,400 miles). The Belly Band breaks up into individual mountains that reach heights of about 10 kilometers (6 miles) along the equator.* *Image: NASA/JPL/Space Science Institute*

article on its own. It was, in a way, a "gift from heaven," because it took place only because of certain communication problems between the *Huygens* probe and the *Cassini* orbiter that became apparent in 2000. At the time, it was realized that during *Huygens*' descent onto Titan, the Doppler effect would push its radio signal outside the range of *Cassini*'s onboard receiver. The eventual solution was to add an extra orbit to *Cassini*'s flight plan, which would include an additional, but very high-altitude, flyby of Titan and would reduce the Doppler effect to within the margins of the *Cassini* receiver. This extra orbit around Saturn led—by pure luck—to a passage near Iapetus with a closest approach distance of about 124,000 kilometers (77,000 miles) instead of 670,000 kilometers (415,000 miles) in the original plan.

The B/C flyby led to several important discoveries. The equatorial ridge was observed as hoped, but there was more: in bright north-polar terrain, we saw craters with dark rims that face toward the equator, and in the dark terrain of the midlatitudes, we found craters with bright rims facing the poles. From *Voyager* data, we had known of the existence of craters whose walls differ sharply in their brightness, but we initially thought that this contrast was correlated with the movement direction of Iapetus within its orbit around Saturn. The discovery that the relative brightness in fact depended on polar orientation proved to be a potentially significant clue in resolving the dark/bright dichotomy riddle.

The B/C flyby also produced the best-ever imaging of the "moat crater" lit by "Saturnshine"—sunlight reflected from the planet. This feature received its nickname from low-resolution *Voyager* images, in which the crater appears as a dark ring, giving Iapetus the appearance of a white astronaut helmet with a black visor and a large hinge—the moat. In *Cassini* images, we identified the moat as an unusually fresh-looking crater with a very complex dark-bright pattern.





The transition from Iapetus' dark leading side to its bright trailing hemisphere does not appear in subtle shades of gray, but instead is a complicated patchwork of craters filled with dark material and highlands that are bright. The area shown here is 711 kilometers (442 miles) by 417 kilometers (259 miles). At center right of this view, taken near Iapetus' equator, are the large mountains shown in the center image. Their western flanks are bright, but the surrounding lowlands generally are dark. *Image: NASA/JPL/Space Science Institute*

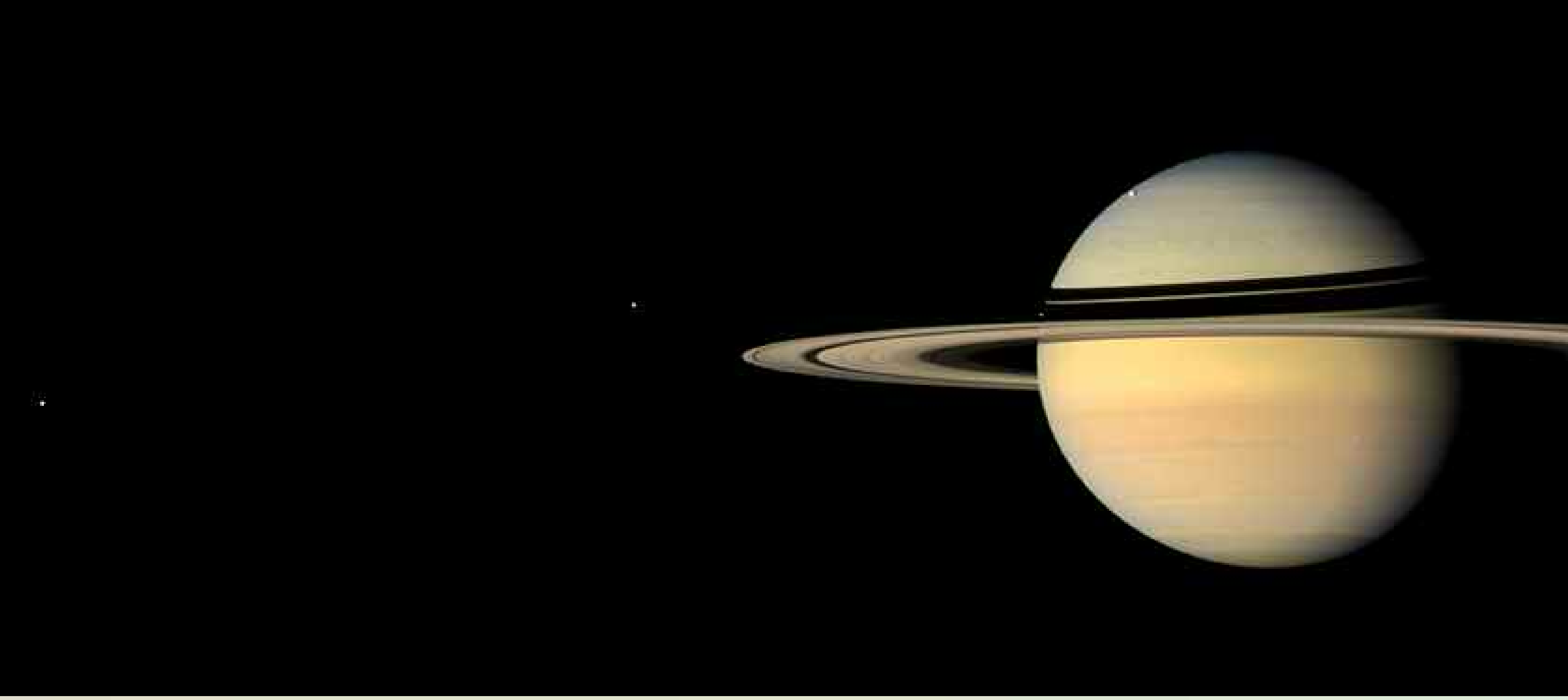
Planning, Negotiating, and More Planning

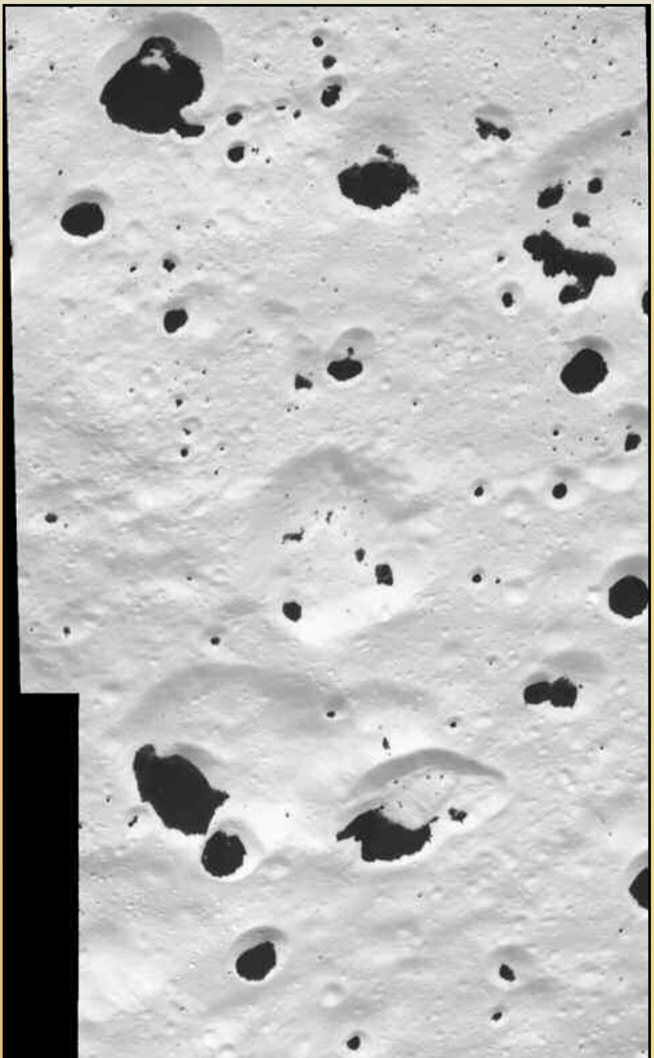
At an April 2004 meeting at the ESA center in Noordwijk, Netherlands, the *Cassini* ISS team and the *Cassini* VIMS (Visible and Infrared Mapping Spectrometer) team reached a vital agreement in terms of how to handle the closest approach part of the flyby. The two teams had been at odds because they had very different needs for their instruments to work optimally. Imaging requires a lot of shifting the spacecraft back and forth to create image mosaics, but short periods of actual exposure over the targets, whereas the VIMS spectrometer benefits from long "sit-and-stare" periods.

At Noordwijk, we agreed that during the three hours after closest approach, we would spend at least two thirds of the time in "sit-and-stare" mode and no more than one third of the time slewing between different targets on the surface. During this meeting, we also presented the broad outlines of our plans for observing the Voyager Mountains at high resolution: this would enable us to create detailed mosaics of the equatorial transition zone and the western terminator, as well as produce a multicolored image of the dark-floored crater Hamon.

Nevertheless, our plans still did not include any imaging during the time the spacecraft neared Iapetus immediately before and also during closest approach. In an attempt to find a solution, I brought the issue to the attention of the ISS team in early 2006 and received their support for renewing our discussions with the *Cassini* navigation team regarding this problem. Perhaps, I wondered, with only modest deviations of the flyby trajectory, could a different star be found that would be occulted by Iapetus maybe 30 minutes or more before *Cassini*'s closest approach?

In summer 2006, Fred Pelletier from the *Cassini* navigation team contacted me on this issue. Fred looked at possible deviations of the flyby time, the minimum altitude, and the B-plane angle (if the spacecraft passes the moon to the left, to the right, above, or below), and the effects of all of these on fuel consumption, or "Delta-V" (velocity change of the spacecraft due to a maneuver). His conclusions did not sound promising at first. It seemed that all but the smallest deviations from the originally selected flight path would cost the spacecraft dearly in terms of precious fuel to correct. Nevertheless, Fred sent me a list of possible minor trajectory changes that looked acceptable for the navigation team. To my great surprise and enormous pleasure, the list contained one deviation that had Iapetus occulting the star Sigma Sagittarii more than one hour before closest approach! From that moment, I was eager to push the development of this alternative trajectory in a way that would satisfy all the teams.





In some places, the spotty black-on-white of Iapetus' transition zone looks like the coat of a Dalmation. The bright material on the moon's frozen surface is water ice, and the dark material, preferentially found at the bottoms of craters, probably is carbonaceous in composition. This view, taken by Cassini*'s narrow-angle camera, is from the hemisphere that faces away from Saturn. The image scale is about 32 meters per pixel.* *Image: NASA/JPL/Space Science Institute*

Everybody Wins

It worked! After going through a more detailed analysis with Fred, we brought the new trajectory before the SOST group, which endorsed it enthusiastically. Soon *Cassini*'s project scientist was convinced, and eventually the *Cassini* project manager was as well. In January 2007 he gave the navigation team the go-ahead to incorporate the trajectory tweak into the spacecraft's official plans.

It's rare to have a situation in life in which everybody wins, but in this case almost every instrument on board the spacecraft benefited from the change: the ORS instruments could now perform their high-resolution surface studies continuously, starting 45 minutes before closest approach. The Voyager Mountains could now be observed rising over the horizon, and the dark terrain ridge would now be covered partly by high-resolution imaging. This additional observation time would also enable the spacecraft to make a large roll, allowing the fields-and-particles instruments to sample data of high quality—a major gain, because the spacecraft attitude in the original trajectory had been very bad for them, but now a better orientation could be selected for the period around closest approach, before the roll.

Even the UVIS star occultation was better now. The improved data collected by *Cassini* on Iapetus' orbit showed that the moon would not in fact occult the original star, Zeta Ophiuchi, but only graze it. With the tweaked trajectory, the new occulting star, Sigma Sagittarii, would indeed disappear behind the moon and would do so at a slower pace, allowing more time for the UVIS instrument to gather data. Last but not least, as a ripple effect, the new trajectory also allowed for a stellar occultation by a volcanic plume from the moon Enceladus during a later orbit.

Final Preparations

In early 2007, we began work on the final pointing and shutter commands. In addition to coordinating the various ISS observations, my colleague in Berlin, Thomas

On September 9, 2007, as Cassini *sped toward its rendezvous with Iapetus, it swung around and took this panoramic view of Saturn and six of its satellites.*

Moons visible in this image are Dione at center left, Enceladus near the left side ansa (or ring edge), Mimas as a speck against the ring shadows on Saturn's western limb, Rhea against the bluish backdrop of the Northern Hemisphere, Tethys (1,071 kilometers, or 665 miles, across) near the right ansa, and Titan (5,150 kilometers, or 3,200 miles, across) near lower right.

Image: NASA/JPL/Space Science Institute

Roatsch, and I had the task of planning precisely where the spacecraft should point during the period 55 minutes before to 3 hours after closest approach. This task required not only balancing the demands of the VIMS and ISS instruments but also implementing specific requirements of the CIRS spectrometer and the fields-and-particles instruments.

We had to fit a total of 11 different image mosaics, along with 65 surface pointings ("footprints") and 252 shutter actions, into this time frame. Our planning activities for the camera were hampered by the fact that we had not yet seen large parts of the trailing side of Iapetus at sufficient resolution to determine the proper exposure times. There were strong indications that these areas are among the brightest on Iapetus—but how bright, exactly? Fortunately, *Cassini*'s 12-bit cameras are robust against such uncertainties, and I was relatively confident that my guesses would be adequate. However, it was only after we received low-resolution data in early July confirming that the exposures had been set right that I was truly able to sleep well at night.

It was also in July that the final commands that would guide the spacecraft through its Iapetus flyby were set in stone. The only remaining uncertainty now was the 70-meter Deep Space Network dish in Madrid, which would receive large parts of the data transmissions from the spacecraft. The Iapetus flyby was to take place near the end of a maintenance period, and it was unclear until very late in our planning if the giant dish would be back online in time.

Approaching the Mystery Moon

We took the first images showing Iapetus as a thin crescent on September 3 at a resolution of nine kilometers (about six miles) per pixel, and they looked much as we expected. However, subsequent observations on September 5–7 included some blank images. Fortunately, I managed to figure out the cause and realized that the same mishap would not occur for the top-priority data. Early on September 9, *Cassini* produced a mosaic of Saturn and its biggest moons "as seen from Iapetus," showing how Saturn would look to a future Iapetus astronaut.

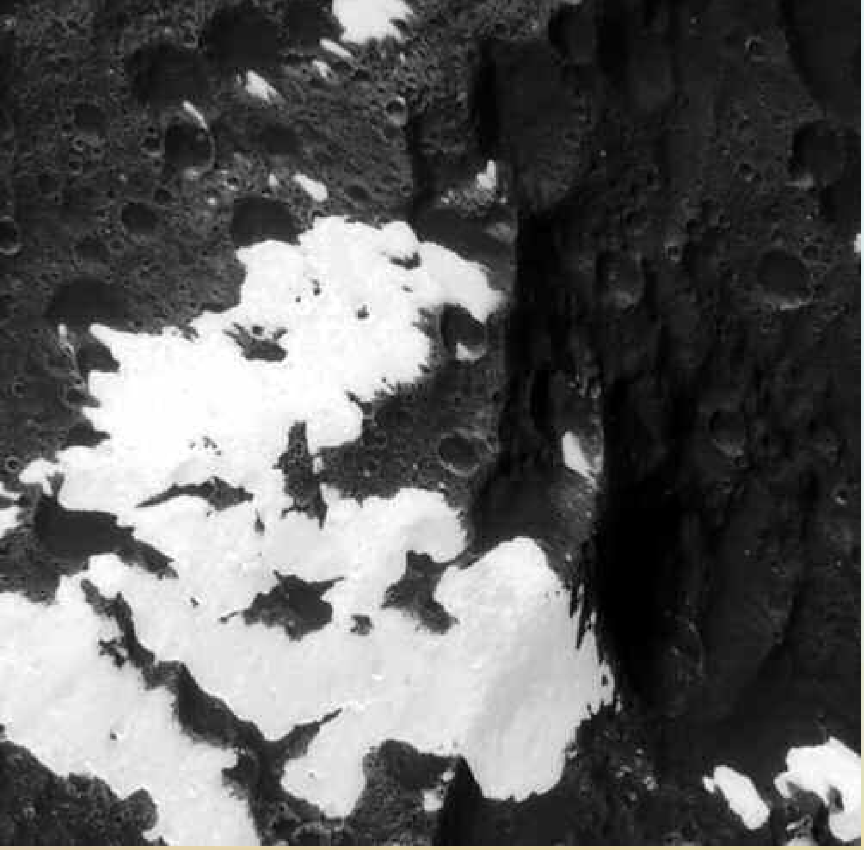
At this point, *Cassini* was so close to Iapetus that the moon no longer fit within the field of view of the spacecraft's narrow-angle camera. Because of problems with NASA's Deep Space Network, only one of two ISS mosaics of Iapetus' growing crescent—taken about half a day before closest approach—made it back to Earth. Fortunately, the one we got was the higher-quality mosaic. The CIRS instrument was less lucky: it lost a very important polarization observation.

Our highest priority now was to record data beginning 5 hours and 25 minutes before closest approach at an altitude of 45,000 kilometers (28,000 miles) above the moon's surface. On Monday morning, September 10 (European time), two of the most important events of the year were taking place at the same time: *Cassini* had its closest encounter with Iapetus, and my son had his first day in a new school. The school's inauguration ceremony exactly coincided with the most important activities at Iapetus. As I enjoyed the ceremony, I followed in my mind what the spacecraft was doing each moment.

Getting the Data—A Bittersweet Story

Initial data from the closest approach began arriving in the middle of the night in Europe, and by the following morning, we had two new images. The timing was selected so that the Deep Space Network stations at Goldstone and Canberra could track *Cassini* at the same time, providing a bit of insurance that no data would be lost. This strategy worked—besides imaging and other data, the most important radar data made it back to Earth with the downlink.

The bulk of the data were expected to arrive in mid-



A close look at the Voyager Mountains was a major quest for the Cassini *team. The scientists first discovered the mountains in 1999 while looking through* Voyager 2 *data. The mountains turned out to be mainly dark, with bright patches seemingly draped over them. This image was taken at a distance of 9,240 kilometers (5,740 miles) from the surface. The scale is 55 meters per pixel.* Image: NASA/JPL/Space Science Institute

morning, and indeed, a few images of the ridge appeared on the screens. For many hours after that, however, no data followed. At first, I thought that the real-time data stream from the JPL computers to the imaging team servers in Boulder, Colorado, had been interrupted, but after several hours of silence I became nervous. Finally, in the late afternoon European time—morning in California—I received a phone call from JPL. It seems a cosmic ray hit triggered a switch in *Cassini*'s transmitter, and the spacecraft responded by stopping all activities, including data transmission. It was the first time in more than four years that the spacecraft had gone into safe mode.

This "cosmic" bad luck was disappointing because it became clear immediately that the observations planned for the subsequent days as the spacecraft was moving away from Iapetus would not take place. The losses included not only a global multicolored mosaic of the trailing side and other observations of Iapetus but also some important and unique observations of Saturn. The spacecraft, in fact, would not be operating any of its science instruments for several days.

Fortunately, the spacecraft navigational systems could be returned to operation within hours. This was very important, because the crucial maneuver designed to bring *Cassini* back to its original trajectory, using 11 kilograms of propellant, was to take place only three days after the flyby. If this maneuver had been missed, *Cassini* would have needed to expend a huge amount of fuel to be put back on track.

The other lucky fact was that the entry into safe mode occurred at the beginning of the downlink, after *Cassini* had acquired all the Iapetus flyby data. If the spacecraft had entered safe mode one day earlier, all the data from the flyby would have been lost.

A Quest Completed

Later that night, the DSN station in Goldstone, California picked up the data stream once more, and a large number of images began flowing in. The Voyager Mountains turned out to be bright patches on mainly dark mountains; the dark/bright boundary appeared very complex; and, strangely, the terrain was either dark or bright but almost never gray—much like a Dalmatian dog's coat.

All the dark crater walls were facing the equator, whereas the bright walls were facing the poles at the moon's low and mid latitudes. The ridge appeared continuous to a certain point, then turned into separate isolated ridges that continued up to the location of the first, easternmost of the Voyager Mountains. The images of this mountain, seen rising over the horizon, arrived near midnight. I could finally see what I had been hoping to see for more than seven years.

Surprisingly, the mountains looked very similar to what I had expected, yet they were somewhat different. I expected their pyramidal shape, but I did not anticipate their level of brightness. The visible eastern flank is actually covered by dark, not bright, material. (This turned out to be a lucky break, because the exposure time had been set slightly too long, and this mountain would have been overexposed if its bright patches extended to its eastern flank.)

We discovered another feature in the images that we had hoped to find: small, bright craters in the dark terrain. We hadn't detected any during the B/C flyby, and we had some doubts as to whether the craters actually were there. With the detection of these small craters—mostly smaller than a football stadium—we can now roughly estimate the thickness of the dark material and the length of time it takes a fresh, bright crater to turn as dark as its surroundings.

In retrospect, the Iapetus flyby was one of the most challenging as well as one of the most exciting satellite flybys of the *Cassini* mission. Unfortunately, some of the data collected from the moon were lost irretrievably, mostly because the spacecraft entered safe mode at a crucial time. Fortunately, however, we received nearly all the top-priority data we had hoped for, and only less important images were lost. This means that possibly the only Iapetus flyby to take place during the lifetime of most of us can be considered a big success. All the data, not just the images, are wonderful, stunning, strange—and alien.

Tilmann Denk is a Cassini *Imaging team associate working at the Freie University in Berlin, Germany. He is responsible for the imaging observation planning, especially of Saturn's moons Dione, Rhea, Iapetus, and Phoebe.*

World Watch

Washington, D.C.—On December 20, 2007, the U.S. Congress passed the fiscal year 2008 budget for NASA and other federal agencies. Passage came just hours before Congress recessed for a three-week holiday.

The holiday presented only a lull in the drama. President Bush had threatened to veto the appropriations bill because of unsettled battles with Congress concerning other budget issues. Just before the New Year, however, Bush signed the legislation, and NASA finally had a 2008 budget, even if it was three months overdue. The total of $17.3 billion for NASA, a 3.1 percent increase from 2007, was consistent with the administration's request. NASA was the only federal science agency to receive an increase.

This budget represents a victory for Planetary Society members. Funding for both space and Earth science was increased, restoring many of the cuts proposed by the administration. Society leaders had testified to Congress, and our members conducted a grassroots SOS: Save Our Science! campaign against the proposed cuts. We should all be proud of this result (see box).

The Constellation program—which includes the new human-rated launch vehicles, Ares and Orion, and the lunar program—was fully funded. Congress supported the Mars program, calling for a launch at every opportunity. Unfortunately, just one day after Congress recessed, NASA announced the postponement of the 2011 Mars Scout mission due to a procedural problem in the proposal process.

Congress included a strange provision in the appropriations bill: "No funds should be spent by NASA on any activity exclusively for human missions to Mars." The provision had no effect on NASA programs, because no planned activity focuses on such missions. It was included to forestall budget attacks from those in Congress who fear making a commitment to send humans to Mars. To ensure that this provision does not become a weapon against all human exploration, The Planetary Society will fight it.

We had campaigned for a new start for a Europa mission to investigate that moon's subsurface ocean, a possible haven for extraterrestrial life. Congress and the National Academy of Sciences have made Europa their top priority. In the budget, Congress provided meager additional funds for outer planets exploration studies but did not choose among several candidate missions to moons of Jupiter or Saturn. NASA expects to select one of these moons for the next "flagship" mission to be proposed to Congress. Our hopes for a Europa mission likely will be realized but delayed.

Reversing years of de-emphasis, Congress boosted Earth science and observation missions and specifically allocated $40 million to begin implementing the National Research Council decadal plan for Earth science. This is a crucial step in improving our understanding of global climate change, another priority of the Society and one about which we testified to Congress last year.

The final budget increased space science research and analysis by $24 million. The science community, along with Society members, had strongly protested cuts in this area, including a 50 percent cut to astrobiology.

Also over NASA's objections, Congress added $38 million for the Space Interferometry Mission to advance the search for planets around other stars. Most of the additions to the NASA budget came at the expense of advanced technology work already under way in the exploration program. These cuts will affect plans for human flights to the Moon and Mars, and they raise concerns about NASA's ability to meet expectations in the Vision for Space Exploration. Although the congressional actions decrease budget conflicts between science and human exploration, they do not lessen the concern that the only way NASA can fund its Constellation program is to take money from science.

Cape Canaveral, FL—Space shuttle *Discovery* was scheduled to launch in mid-December last year, but as we go to press, its earliest expected launch date is now February 2008. Delays add pressure to NASA to finish the International Space Station assembly and retire the shuttle by the end of 2010. In addition to getting the European Columbus and Japanese Kibo modules into orbit, the all-important Hubble servicing mission still must be completed.

A bill introduced by Senator Dave Weldon (R-FL) proposes to keep the shuttle flying to the International Space Station after 2010. If this were to happen, the entire Vision for Space Exploration would be undermined, and NASA would need to redirect funds from the exploration program to the shuttle.

Louis D. Friedman is executive director of The Planetary Society.

You Did It!

You and your fellow Planetary Society members make up the largest grassroots space advocacy group on Earth, and our ability to demonstrate public support for space exploration is perhaps our strongest asset.

Time and time again, you have responded to calls for action with letters, cards, e-mails, phone calls, and petitions to government officials. All those who care about space exploration and the search for extraterrestrial life, and who explore other worlds and seek to understand our own, repeatedly thank our members for helping to Save Our Science.

This year will see new issues, and as the United States prepares to choose a new administration, we expect many more calls for action to guide the space program. We will need you more than ever! Thank you again for your support. —*LDF*

We Make It Happen!

by Bruce Betts

Stars Above, Earth Below: Astronomy in the National Parks

The Planetary Society is sponsoring Tyler Nordgren in his quest to visit 12 National Parks in one year and explore the connections between planetary science, parks, astronomy, the public, and dark skies. His blogs, which include his incredible pictures, can be found on our Planetary Society website at *planetary.org/parks*.

Tyler is an astronomer and associate professor of physics at the University of Redlands in California. He came to The Planetary Society asking for financial help with his creative idea to connect the parks and the wonders of the night sky. He is about halfway through his visits, from the icy grandeur of Denali National Park in Alaska to the red rocks and steep-walled canyons of Bryce Canyon National Park in Utah. As he meets with park experts and visitors, he examines the themes that link the parks to other landscapes in the solar system, and he writes about what he discovers on The Planetary Society's website. Through it all, he enjoys the uniquely dark skies that grace most national parks, a resource that is quickly vanishing from the rest of the country.

For many U.S. residents, as well as for those in many other countries of the world, the only contact possible with truly dark skies is during visits to large national parks. As a result, there is a natural connection between the two, an opportunity that Tyler hopes to exploit to engage national parks visitors in the wonders of astronomy.

The connections also take the form of planetary analogs. For example, he is exploring connections between geysers in Yellowstone Park and those on Saturn's moon Enceladus, and between the red rock canyons of Utah and the Grand Canyon and canyons on Mars.

This pictogram of the Moon and a star appears underneath an overhang near the Great House of Peñasco Blanco in Chaco Culture National Historic Park, New Mexico. Is this the Crab Nebula supernova of 1054? Perhaps it simply represents Venus near a crescent Moon. Beneath it, on an exposed section of wall, is a pecked-out spiral with a painted flaming tail of red. Halley's comet appeared only 12 years after the supernova. Photo: Tyler Nordgren

What's Up?

In the Sky—February and March 2008

Orange-red Mars is high overhead in the evening sky, and slightly yellowish Saturn is in the east. In the predawn eastern sky, extremely bright Venus is to the lower left of bright Jupiter. Venus and dimmer Mercury appear close together throughout March and can be seen low in the east before dawn.

Random Space Fact

Explorer 1, the first American satellite, was launched 50 years ago, on January 31, 1958. Data returned by *Explorer 1* and *Explorer 3* (launched in March 1958) provided evidence that Earth is surrounded by intense bands of radiation, now called the Van Allen radiation belts after their discoverer, James Van Allen.

Trivia Contest

Our September/October contest winner is Ken Humphrey of Lake Elsinore, California. Congratulations!

The Question was: Who has more time in space than any other human? (Hint: The time was accrued over several missions) *The Answer is:* Sergei Konstantiovich Krikalyov, at 803 days.

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

What is the oldest spacecraft still in space?

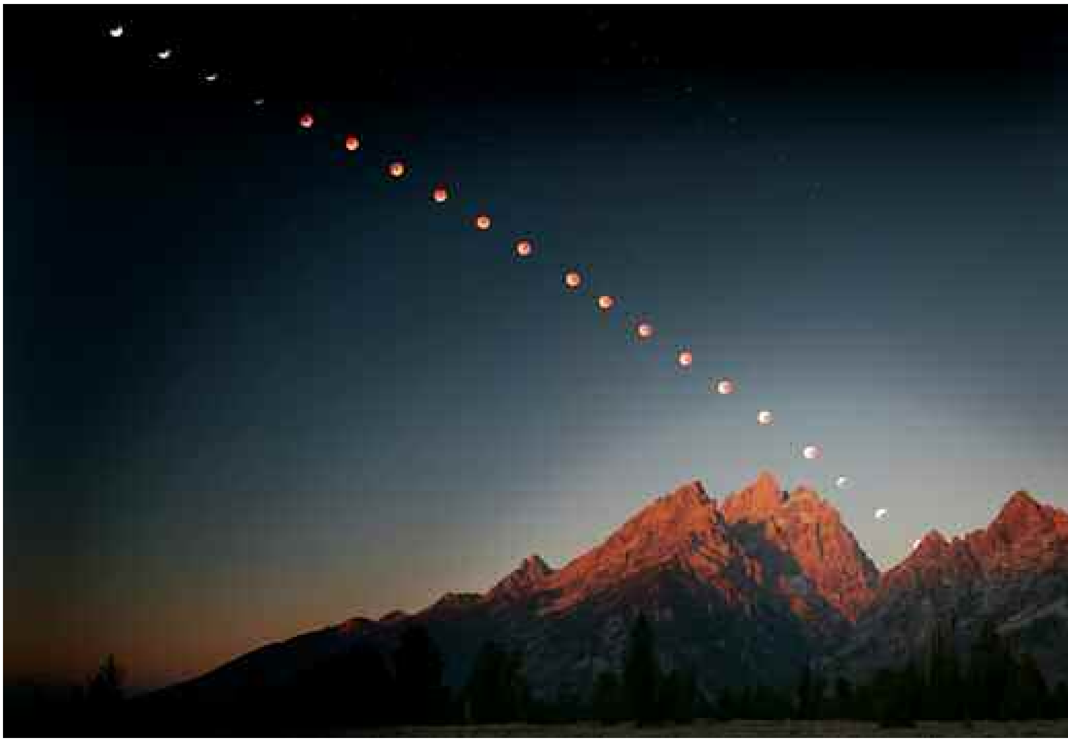
E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 65 North Catalina Avenue, Pasadena, CA 91106. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). Submissions must be received by April 1, 2008. The 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.*

In some cases, the connection between astronomy and parkland isn't simply left to the mind's eye. For a number of parks in the American Southwest, monuments and rock wall markings are arranged in alignment with the Sun and Moon on special dates determined by the orientation of the Earth in its orbit around the Sun. Standing in the presence of one of these structures on a spring equinox, one is struck by how long astronomy has been a part of these places, as well as by how the night sky is not just a natural resource but a cultural one as well.

Tyler is getting help from the National Park Service and its Night Sky Team of rangers and astronomers. You can find out much more about his fascinating journeys at our website at *planetary.org/parks*. Don't forget to check out the amazing pictures!

Bruce Betts is director of projects for The Planetary Society.



On the night of August 29, 2007, Tyler Nordgren camped out at just the right spot to watch the eclipsed Moon set just to the right of the Grand Teton in Wyoming. He took an exposure of the Moon every 10 minutes until it disappeared and the Sun lit up the mountains with alpenglow. Photo: Tyler Nordgren

Members' **Dialogue**

Pioneer Anomaly

This letter came in response to our member update describing how your donations have helped save precious Pioneer 10 *and 11 data and, we hope, take us closer to understanding the* Pioneer *anomaly.* —Editor

This is indeed excellent news. I joined the Society about a year ago and have to admit that I was not really sure whether this would make sense. Now I am happy I made this decision!

The *Pioneer* puzzle is interesting for everyone who hears about it. It makes people realize how strange it is (at first) and, at the same time, how fascinating it can be to think about the universe that surrounds us and of which we are a part. Too often daily life forces us to focus on problems related to our life here on Earth. I have, however, experienced very often how people got interested and inspired when I told them about the *Pioneer* anomaly. It was the starting point for a wonderful evening of discussions about astronomy and cosmology.

Even if the *Pioneer* anomaly finally turns out to be a technical problem, I believe that it had a very positive impact!

—ANDI BURKERT,
Munich, Germany

Let's Just Go!

I was beset with sadness as I read "Worlds Beyond," Andre Bormanis' article on the future of human space exploration in the November/December 2007 issue of *The Planetary Report*. When the United States first put humans on the Moon, I thought I would live to see them land on Mars. As I read the article, it became apparent that I won't even live to see us make the next step. "Back to the Moon" seems to be the best we can come up with. Is that really the best way to spend our money, to repeat what we did 35 years ago just because other nations now find they can do it?

We've known for 10 years now that we could go to Mars with a small improvement to *Apollo* technology (see Robert Zubrin's *The Case for Mars* and NASA's "Design Reference Mission") in an affordable, 10-year program, and yet we seem to exaggerate the dangers and get sidetracked with what other nations are doing. We're spending our money reinventing heavy-lift rockets and space capsules instead of just saying "Let's go!"

I agree with Zubrin that mission dates 20–40 years out pretty much guarantee we won't do anything. The current (non) plan for human space exploration is a formula for wasting money and doing nothing.

—LARRY ALTER,
Seminole, Florida

Please send your letters to
Members' Dialogue
The Planetary Society
65 North Catalina Avenue
Pasadena, CA 91106-2301
or e-mail: *tps.des@planetary.org*

Questions and Answers

I am a mathematics instructor at a university, and experience has taught me how easy it is to "lose" students by teaching at a level that is too high, even though it may not appear as such to me. This has made me think about our civilization's exciting SETI efforts.

Is it possible that communications (even intentional ones) from extraterrestrial civilizations might be, to our relatively simple minds, so complex as to appear as random noise that would be dismissed as having a natural cause? If this is plausible, then SETI efforts should focus on star systems that are likely to be at a similar stage in their life history, rather than systems of great antiquity near the center of the galactic disc.

Denizens of the former star systems are more likely to pitch their signals at the right level for us.
—Chris Bauch
Guelph, Ontario, Canada

Although it would be nice to focus our SETI efforts on star systems that might have civilizations at a technical level comparable to our own, there's no way we can do this. Sure, we have some astronomical techniques for estimating the ages of Sun-like stars, but the accuracy of these estimates is seldom better than a billion years or so. Therefore, it's impossible to narrow down our choice of SETI targets to only those star systems where the age of the planets is the same as the age of Earth—not even within a few million years. Furthermore, even if we could identify solar systems that are exactly the same age, who's to say that the rate of evolution on their world would be precisely the same as the rate on ours?

Your other point, namely that advanced societies might be putting out very complex signals, has been bandied about by SETI researchers for many years. According to information theory, the optimal encoding of a radio message would make it seem just like random noise—the type of signal that, as you note, we would probably throw out as a natural process.

It's plausible, however, that at least some transmissions made in our direction are deliberate: sent by

Factinos

The European Space Agency's *Venus Express* spacecraft has confirmed the presence of lightning on Venus (see illustration below). Scientists know of only three other planetary bodies in the universe that generate lightning—Earth, Jupiter, and Saturn. "In addition to all the pressure and heat, we can confirm there is lightning on Venus—maybe even more activity than there is here on Earth," said team member Christopher Russell of the University of California, Los Angeles.

This is how lightning might look in Venus' thick sulfuric acid atmosphere. The European Space Agency's* Venus Express *has detected "whistlers," brief, low-frequency electromagnetic wave signals that confirm the presence of such lightning on our sister world. *Illustration: ESA, C. Carreau*

Lightning on Venus is important, scientists say, because such electrical discharges can alter the chemistry of an atmosphere. Russell said the Venusian lightning is unique in that it's the only lightning known not to be associated with water clouds. Instead, on Venus, the lightning is associated with clouds of sulfuric acid.

The researchers used data obtained from *Venus Express*' magnetometer to make measurements of the electrical discharges that confirmed lightning. The measurements were taken once a day for two minutes, during a period when the spacecraft was closest to Venus. A Venusian day is about 117 Earth days long.

A report on this discovery was published in the November 29, 2007 issue of *Nature*.
—from United Press International

Voyager 2 has followed its twin, *Voyager 1*, into the heliosheath, the vast region at the edge of our solar system where the solar wind collides with the thin gas between the stars. *Voyager 2* took a different path, however, and crossed this boundary on August 30, 2007, almost three years after, and about 16 billion kilometers (10 billion miles) away from, *Voyager 1*. Here it made the startling discovery that the heliosphere, the bubble carved into interstellar space aliens trying to get in touch. In that case, they'll make part of the broadcast easily visible. Very narrow-band signals, the type that SETI traditionally has sought, are great beacons that would say: "Listen more closely. There's a transmitter here." Even spread-spectrum transmissions, the type that many contemporary cell phones use, can be detected if you have enough computer power. SETI practitioners are already looking ahead a few decades, anticipating a significant drop in computing costs. At that point, they can broaden their search by broadening the signal bandwidth they can detect.

The bottom line is this: while a very advanced society might send us a signal that we couldn't decode—that we'd never understand—it's still reasonable to suggest that we would nonetheless recognize it as a signal. The Trobriand Islanders wouldn't really get the message if you shouted at them in Hungarian, but they would certainly be aware that you were trying to get their attention.
—SETH SHOSTAK,
SETI Institute

Congratulations on your excellent article on the Kebira crater in the July/August 2006 issue of* The Planetary Report. *The feature's age (28 million years) is on or close to the Oligocene/Miocene boundary. This brings to mind the Chicxulub impact, which occurred at the Cretaceous/Tertiary boundary.

Did the Kebira impact cause any extinctions (presumably most noticeable in the microfossil record)? The sedimentary sections in the numerous wells drilled in Egypt, Sudan, Libya, and elsewhere should indicate this impact. What a wonderful time marker.
—Frank R. Shaffer
Harahan, Louisiana

This is a very interesting question. There are three reasons why we have no answer for it yet. First, we have not confirmed that the circular Kebira structure was caused by a large impact. To do so, we will need to collect and analyze compositional and textural samples from the site.

Second, the groundwater wells you mention were drilled without much attention to chemical, mineralogical, or fossil components of the host sediments.

Third, ejecta from the Chicxulub impact, which occurred partly in the ocean, went into the atmosphere and blocked enough of the Sun's radiation to cause an abrupt, major climate change. An impact event in the Sahara would have been less disruptive.

Having said that, the idea certainly deserves attention as we plan detailed studies of the structure.
—FAROUK EL-BAZ,
Boston University

by the solar wind, is not perfectly round but squashed on one side. Where *Voyager 2* made its crossing, the bubble is pushed in closer to the Sun by the local interstellar magnetic field.

The plasma science experiment instrument on *Voyager 2* is still in working order, unlike its predecessor, so it can directly measure the solar wind's velocity, density, and temperature. In addition, *Voyager 2* crossed the shock at least five times over a couple of days. (The shock sloshes back and forth like surf on a beach, allowing for multiple crossings. Three of these show in the data, revealing the unusual shock.)

"The important new data describing the termination shock are still being pondered, but it is clear that *Voyager* has once again surprised us," said Eric Christian of NASA's *Voyager* Program.
—from the Jet Propulsion Laboratory

For the first time, scientists have detected strong evidence of hazes in the atmosphere of a planet orbiting another star (see illustration at right). Frederic Pont of Switzerland's Geneva Observatory and his team used the Hubble Space Telescope to study the planet HD 189733b as it passed in front of its parent star during an eclipse. When the light from the star briefly passed through the exoplanet's atmosphere, the gases in that atmosphere stamped their unique spectral fingerprints on the starlight. Where the scientists had expected to see the fingerprints of sodium and potassium, there were none, implying that high-level hazes, with an altitude of 3,200 kilometers (2,000 miles), are responsible for blocking the light from these elements.
—from *hubblesite.org*

A team of scientists from the Geneva University Observatory has detected strong evidence of hazes in the atmosphere of a giant planet orbiting the star HD 189733b, 63 light-years from Earth in the constellation Vulpecula. This is the first time such atmospheric hazes have been seen in a planet around another star. "One of the long-term goals of studying extrasolar planets is to measure the atmosphere of an Earth-like planet," said Frederic Pont, the research team's leader. "This present result is a step in this direction. HD 189733b is the first extrasolar planet for which we are piecing together a complete idea of what it really looks like." *Illustration: NASA, ESA, and G. Bacon, Space Telescope Science Institute*

For more details about these stories, go to the news archives at *planetary.org*.

Society News

Witness History in the Making!

On May 25, 2008, *Phoenix* will land near Mars' north pole.
Celebrate this momentous event with The Planetary Society
at **Planetfest '08—New Visions of Mars.**

Join co-hosts Ray Bradbury and Bill Nye® The Science Guy for

Planetfest '08—New Visions of Mars

Hilton Pasadena, Pasadena, California
May 25, 2008, 2 p.m.– 8 p.m.
planetfest.org

Stand up and Cheer for Your Successes!

I have watched with delight as the fruits of our labor—yours and mine and all our fellow Planetary Society members'—grow through the solar system. In the case of the *Voyager* spacecraft, they've gone even beyond that.

As 2007 came to a close, *Voyager 2* followed *Voyager 1* into the heliosheath, a vast region on the far edge of our solar system. The two craft continue their legendary mission, introducing us to new regions of our neighborhood as they journey toward interstellar space.

Planetary Society members helped make this happen. Just a few years ago, NASA was ready to shut down all operations of these intrepid explorers. You and your fellow members launched into action and helped persuade NASA officials to change their minds.

You did the same with the Hubble Space Telescope. Preparations are now well under way for the Hubble servicing mission—one that never would have occurred had not the public intervened to protest a decision against it. You were part of that protest.

A recent issue of the prestigious international news magazine *The Economist* lauded SETI@home and its numerous distributed computing spin-offs, including Stardust@home. The Planetary Society was the founding sponsor of SETI@home. The project may never have materialized had our members not provided seed funding when no one else would bet on this novel experiment.

Today, some call this model *citizen cyberscience*. It makes sense, and as with our solar sail, the *Pioneer* anomaly, and our Phobos LIFE experiment, we have shown there is a role for public participation and private funding to help make space exploration happen. After all, our core belief is that you and every Planetary Society member are Planetary Citizens, members of the entire solar system community whose actions affect our planet and all others.

You make a difference. Stand up and give yourself a cheer!
—Louis D. Friedman, Executive Director

Your Gift Planning Today Can Shape Tomorrow's Future in Space

When you watch the images returned from Mars or that show our own planet viewed from space, look out into the universe and wonder if we are alone, or marvel at the discovery of yet another extrasolar planet, you are experiencing the joy of space exploration and our search for our place in the cosmos.

As someone who cares about our planet and those beyond, you have joined with The Planetary Society to search for other life and other worlds today, and you can help us leave a space exploration legacy for future generations.

By planning your gift today—naming The Planetary Society as a beneficiary in your will or estate plan—you can make a significant gift for space exploration tomorrow.

Your bequest to The Planetary Society helps ensure that we can meet new challenges and opportunities. You have a hand in shaping the future of space exploration, and in many countries, you will also receive significant tax benefits. In every case, you will feel good knowing that you are making a difference for future explorers like yourself.

For information about including The Planetary Society in your will or estate plan, please call me at (626) 793-5100, extension 214, or e-mail me at *andrea.carroll@planetary.org*.
—Andrea Carroll, Director of Development

A NEW YEAR OF EXPLORATION!

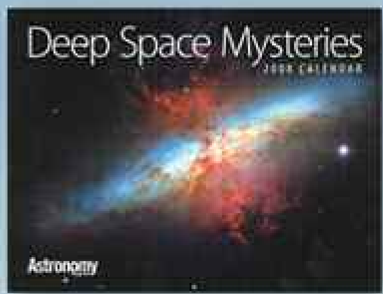
NEW! Commemorative Mars Marble Key Fob
We're going to Mars! The names of a quarter-million people—including all Planetary Society members—are on the way to Mars on board the *Phoenix* spacecraft, which launched in August 2007.

Our Mars replica key fob is emblazoned with the words "I'm Going Here!" with an arrow pointing to the Martian north pole. Don't miss your chance to get this commemorative Mars marble key fob, which features:

- 1-inch-diameter Mars marble made from recycled glass
- Geographic details, including white polar caps, dark canyons, mountains, and volcanoes
- Silver-plated hardware allowing Mars to spin freely

1 lb. **#605** **Regular price: $6.39** **Member price: $5.75**

Set Sail for the Stars! Poster
A solar sail takes off in flight, 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**
Regular price: $15.00
Member price: $13.50



LAST CHANCE—
Deep Space Mysteries: 2008 Wall Calendar
Each month, enjoy magnificent full-color images from deep space. This 2008 wall calendar is produced by the creators of *Astronomy* magazine.
2 lbs. **#520**
Regular price: $12.50 **Member price: $11.25**

Surf Titan T-Shirt
A Planetary Society classic—we first introduced this shirt after *Voyager* passed by Titan, revealing hints of a methane ocean. Now that *Cassini-Huygens* has arrived for a closer look at the mysterious moon, we decided to bring this old favorite out of retirement. This shirt is long-sleeved with "The Planetary Society" printed on the left sleeve. Adult sizes: S, M, L, XL, XXL. 1 lb. **#593**
Regular price: $22.22 **Member price: $20.00**

An Explorer's Guide to Mars Poster
24" x 37" 1 lb. **#505**
Regular price: $16.95 **Member price: $15.25**

"Is Anybody Out There?" Poster
39" x 16" 1 lb. **#320**
Regular price: $15.00 **Member price: $13.50**

Nebula Poster
22" x 34" 1 lb. **#315**
Regular price: $15.00 **Member price: $13.50**

Pale Blue Dot Poster
12" x 30" 1 lb. **#326**
Regular price: $11.11 **Member price: $10.00**

Mars in 3-D Poster
12" x 39" 1 lb. **#306**
Regular price: $15.00 **Member price: $13.50**

***Pathfinder* Images of Mars**
20 slides. 1 lb. **#215**
Regular price: $8.34 **Member price: $7.50**

"Is Anyone Out There?" T-Shirt
Adult sizes: S, M, L, XL, XXL 1 lb. **#586**
Regular price: $22.17 **Member price: $19.95**

Future Martian T-Shirt
Child sizes: S, M, L 1 lb. **#565**
Regular price: $15.00 **Member price: $13.50**

SETI@home Mug
2 lbs. **#550**
Regular price: $11.11 **Member price: $10.00**

We're Saving Space for You! Bumper sticker
1 lb. **#695**
Regular price: $3.33 **Member price: $3.00**

Planetary Society Key Ring Medallion
1 lb. **#677**
Regular price: $17.78 **Member price: $16.00**

Planetary Society Lapel Pin
1 lb. **#680**
Regular price: $3.33 **Member price: $3.00**

Planetary Society Cap
1 lb. **#673**
Regular price: $15.00 **Member price: $13.50**

Spacecraft Science Kits
Each sold separately. 1 lb.
Regular price: $17.50 **Member price: $15.75**

#525 Hubble Space Telescope
#530 *Lunar Prospector*
#560 *Voyager*

"Worlds to Discover" Presentation
2 lbs. **#791**
Regular price: $51.05 **Member price: $45.95**

***Planetary Report* Binder**
2 lbs. **#545**
Regular price: $16.11 **Member price: $14.50**
Special Value—order two binders for $25.00 ($27.78 for nonmembers)!

Order Today!

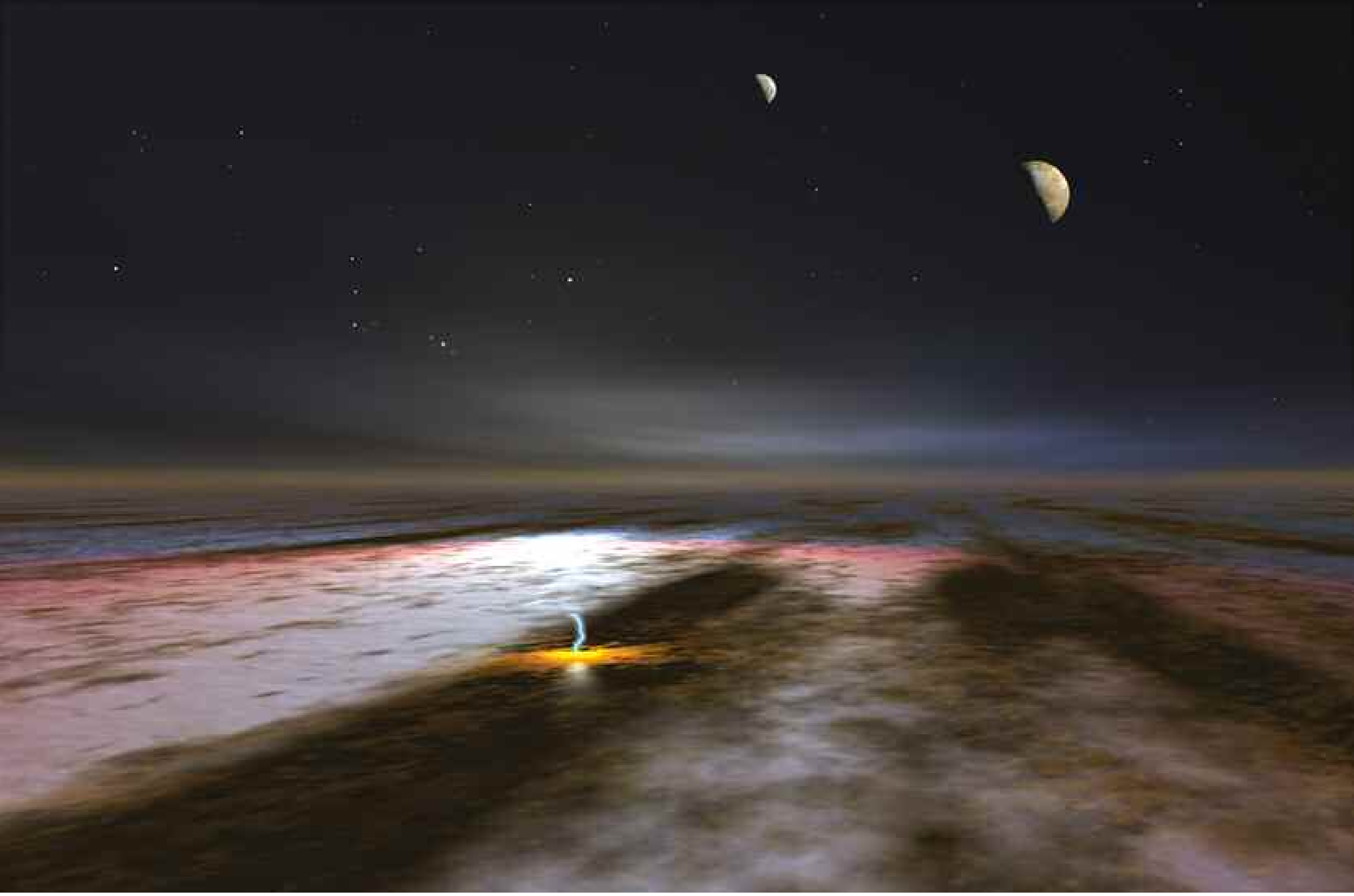
Phone: 1-626-793-1675

Fax: 1-800-966-7827 *(U.S. and Canada)* ***1-626-793-5528*** *(International)*

Shop online at the Planetary Store! http://planetary.org

Use the Members-Only Coupon Code: planet

Attention, teachers—submit your order on your school letterhead and receive a 20% discount.



In *Jupiter's Cloud Tops at Night,* a giant lightning bolt crashes between the gas giant's cloud layers as Io and Europa glow serenely in the sky overhead. This scene is from the altitude of Jupiter's highest clouds, where the atmospheric pressure is just a few millibars—about the same as that on the surface of Mars. Beneath these clouds lies a turbulent realm of gargantuan pressures and tornado-force winds. Deeper still, this atmosphere gives way to a deep, planet-wide ocean of liquid hydrogen.

Walter Myers works as a computer graphics artist and is a member of the International Association of Astronomical Artists. His list of clients includes The Discovery Channel, WGBH/NOVA, National Geographic Television, NASA, and *Astronomy* magazine.

THE PLANETARY SOCIETY
65 North Catalina Avenue
Pasadena, CA 91106-2301

PRINTED ON RECYCLED PAPER
Printed in USA