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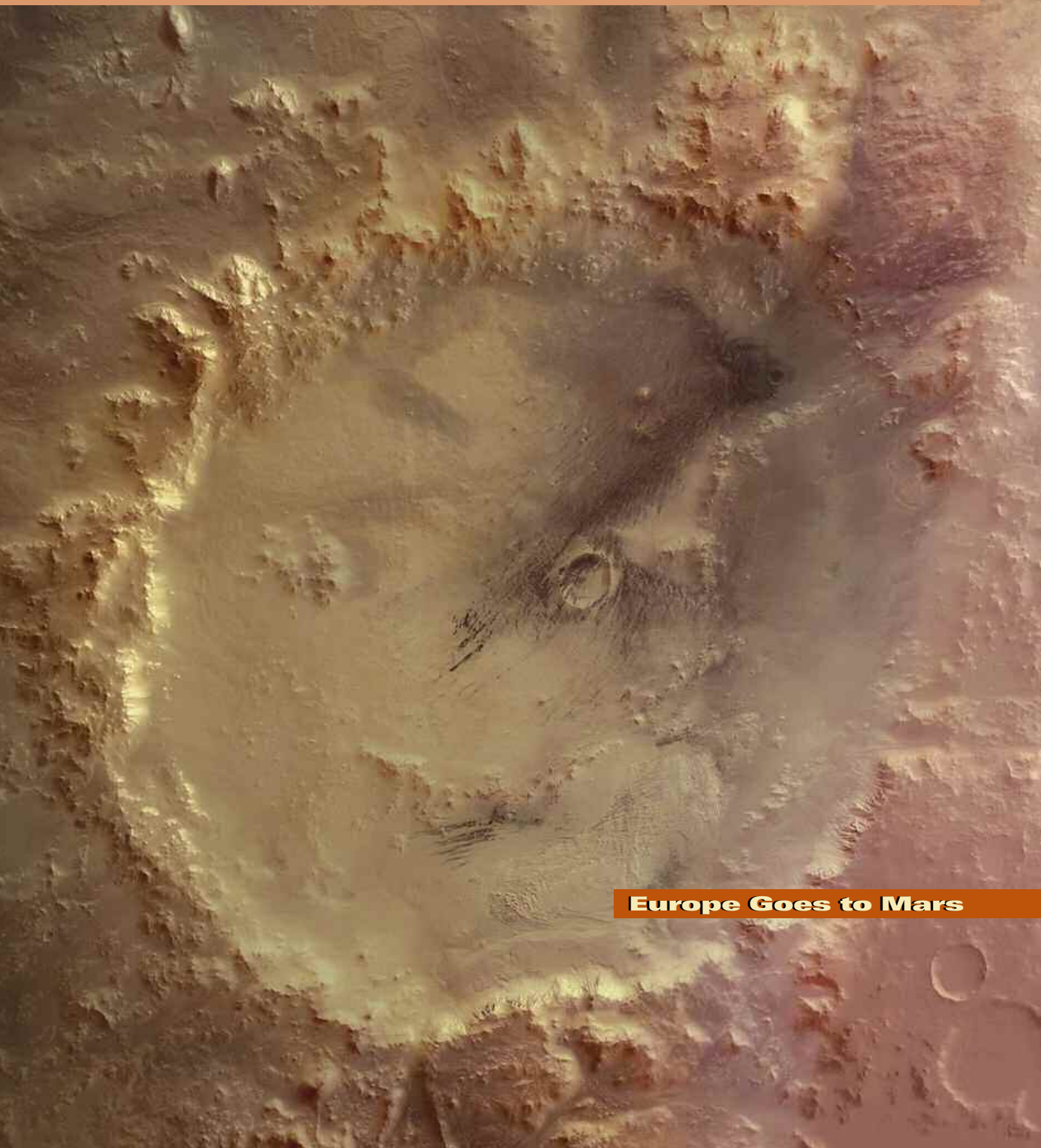

Europe Goes to Mars

From The Editor

When The Planetary Society was founded in 1980, there were two spacefaring powers: the Soviet Union and the United States. In 1986, while the United States sat on the sidelines, the Soviet Union sent *VEGA* to Halley's comet, Japan sent two smaller craft, and the European Space Agency (ESA) sent *Giotto*, whose amazing images of Halley's nucleus transformed our view of comets. Precocious, the European Space Agency was, in its first planetary mission.

Now, Europe has reached a robust maturity in space exploration. Last year, we reported in detail on the *Huygens* probe at Titan, but we've parceled out coverage of ESA's *Mars Express*. *Huygens*' data-collecting life lasted less than four hours, and the data were returned to Earth almost immediately, so summarizing the first results was relatively easy.

As for *Mars Express* . . . it arrived at Mars in 2003, and the mission has been extended twice—and the spacecraft is still working. It carries seven instruments, the mission team is spread over a continent, and we at the Society have a small staff. Nevertheless, A.J.S. Rayl has been tirelessly covering *Mars Express* for our website since its launch and has written a comprehensive story of the mission for *The Planetary Report*, laying out its few glitches and many, many successes.

Rosetta, on its way to comet Churyumov-Gerasimenko, made news before it even got close to its target. Flying by Mars, it picked up a gravitational boost and returned some spectacular pictures you'll see in this issue.

Space exploration is truly an international adventure—one the international Planetary Society's members helped make happen.

Be proud and enjoy the fruits.

—Charlene M. Anderson

On the Cover:

The European Space Agency's *Mars Express* captured this image—a mosaic of overlapping images gathered during five separate orbits of Galle crater, also known informally as "Happy Face" crater. The impact crater is located on the eastern rim of the Argyre Planitia impact basin near 51 degrees south latitude and 329 degrees east longitude. A large stack of layered sediments forms an outcrop in the southern part of the crater (lower part of the image). Several parallel gullies, possible evidence of liquid water on the Martian surface, originate at the inner crater walls of the southern rim. The friendly "face" was first pointed out in images taken by NASA's *Viking 1* orbiter in 1976.

Background:

Mars Express' High Resolution Stereo Camera (HRSC) peers down at the eastern scarp of Olympus Mons, Mars' giant volcano. In places, the scarp is up to six kilometers (35 miles) high. The lowland plains, seen here at bottom, have a smooth surface and show several intersecting channels that are several kilometers long and up to 40 meters deep. Between the edge of the lowland plains and the bottom of the volcano slope are "wrinkle ridges" that border the archlike terraces at the foot of the volcano slope. The image is centered at 17.5 degrees north latitude and 230.5 degrees east longitude. North is to the right.

Images: ESA/DLR/FU Berlin (G. Neukum)

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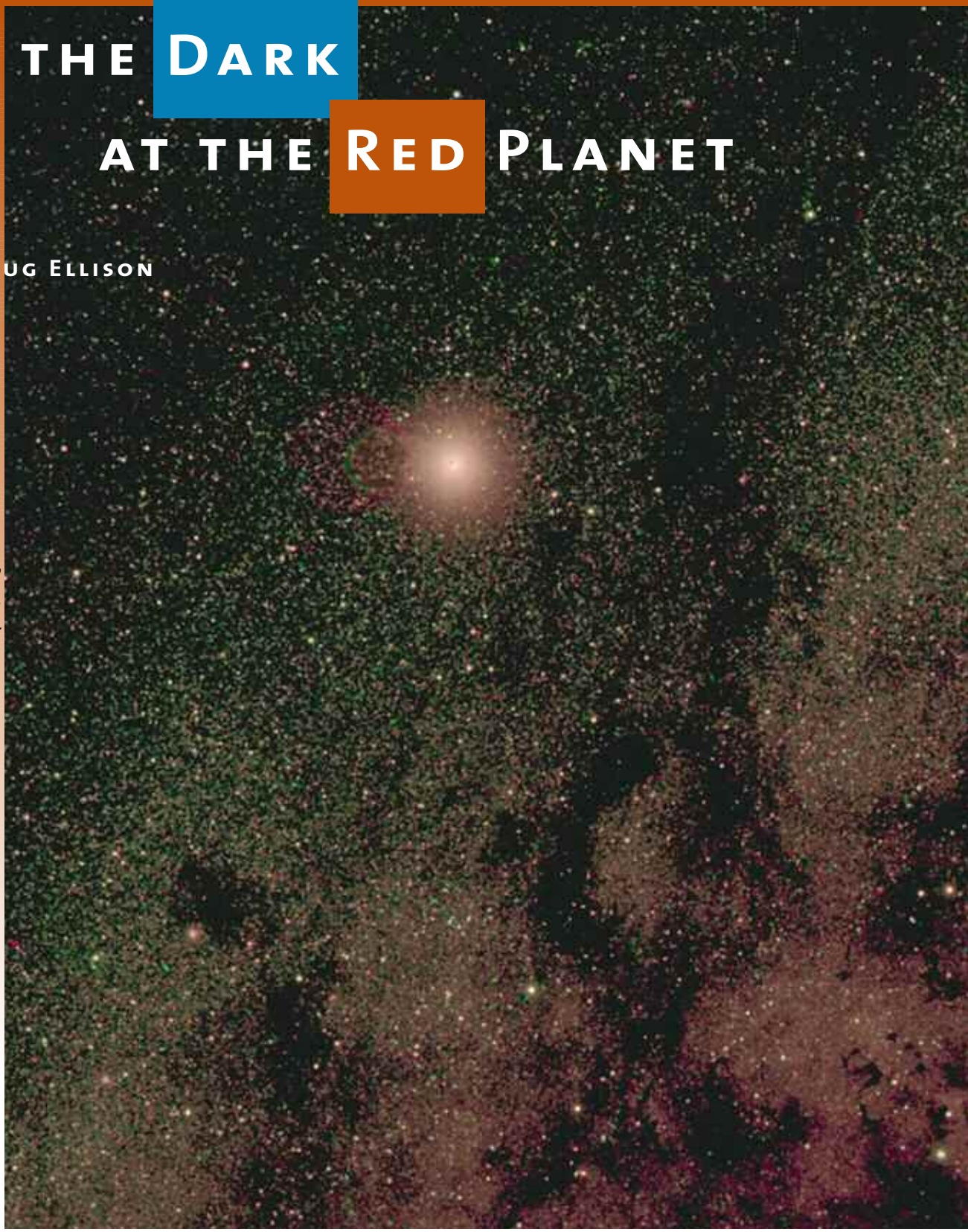
Contents

A PUBLICATION OF THE PLANETARY SOCIETY

In the Dark at the Red Planet

BY DOUG ELLISON

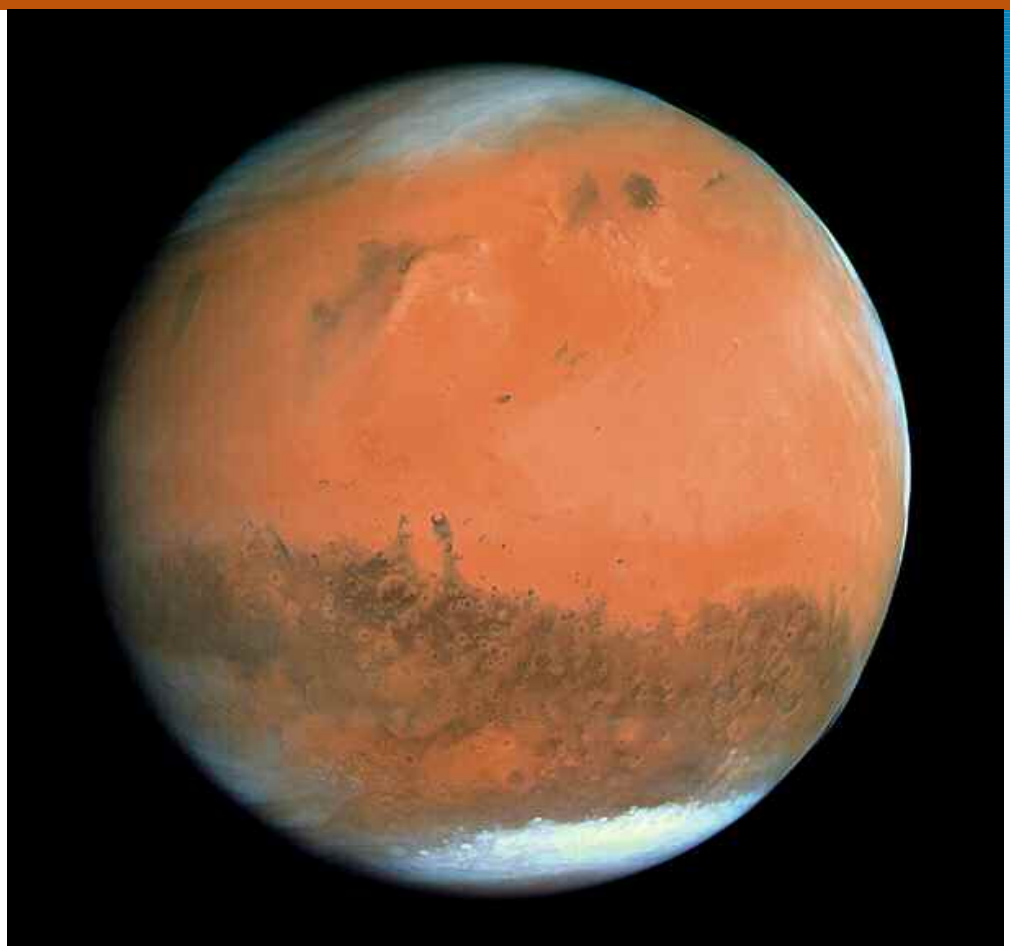


Rosetta *captured this view of Mars shining above the Milky Way on December 3, 2006 as the spacecraft approached for its February 26, 2007 flyby. The view was captured with the OSIRIS wide-angle camera. The camera has a wide, 12-degree field of view that is intended to capture views of the gases in the coma of each of its cometary targets. From a distance of more than 80 million kilometers (50 million miles), Mars is only a point source of light to OSIRIS; it is highly overexposed in this view and therefore surrounded by a halo of scattered light.*

Image: ESA/MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA

"We do not like hide-and-seek parties." These were the words of Jocelyne Landeau-Constantin—the European Space Agency's (ESA's) media relations officer—as the *Rosetta* spacecraft slipped into darkness at the beginning of what we now know was a successful Mars flyby on February 25, 2007.

Rosetta still has seven years to go until it arrives at its final destination—comet Churyumov-Gerasimenko—in 2014 and needs two more gravity assists to gain the energy needed to get there. This exceptionally close flyby of Mars put *Rosetta* on track for two future visits back to Earth and then on to its final orbit that



Just before the spacecraft put itself into quiet survival mode for the eclipse,* Rosetta *sent back this view of the globe of Mars, captured by the OSIRIS camera on February 24, 2007. Early morning and northern polar clouds hover above the reddish surface of Mars.
Image: ESA © 2007 MPS for OSIRIS Team/ MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA

will take it more than five AU from the Sun—farther than any solar-powered spacecraft has been before. (One AU, or astronomical unit, is the mean distance of Earth from the Sun, about 150 million kilometers or 93 million miles.)

A 2002 failure of an Ariane 5 launch vehicle—the rocket scheduled to launch *Rosetta*—pushed *Rosetta*'s launch date from January 2003 to March 2004. The new launch date meant that both the spacecraft's destination—comet P/Wirtanen—and its trajectory needed to be changed. For the engineering team charged with looking after *Rosetta*, one of the biggest changes was that the Mars flyby would now include about 25 minutes of darkness, as the required trajectory to get the spacecraft on its way to future Earth flybys passed through the shadow of Mars—an occultation. This may seem an insignificant change, but the solar-power systems were never designed for 25 minutes of darkness. As the *Rosetta* team counted down to the eclipse, an air of tension filled the European Space Operations Centre (ESOC) in Darmstadt, Germany. Then, Elsa Montagnon's voice came over the network: "All stations on the loop, we have lost the S-band signal, indicating start of occultation." It was 01:56:10.

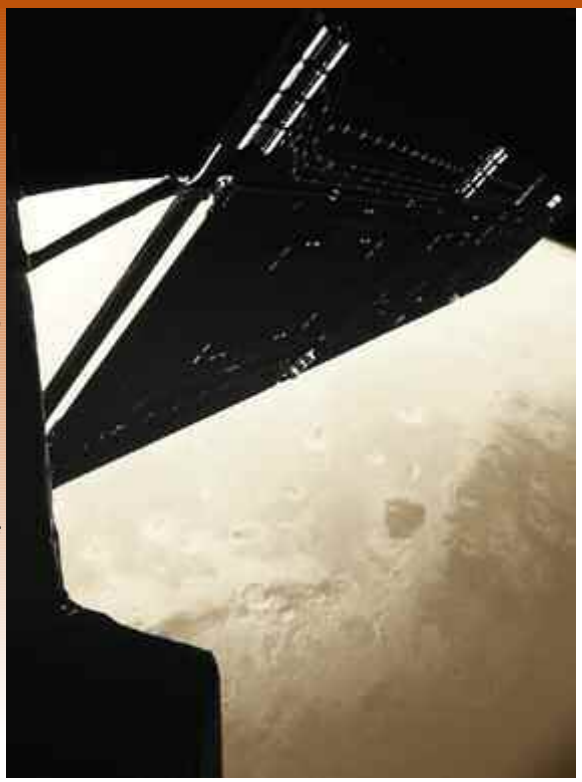
Just 11 kilometers (about 7 miles) from its target point and about 250 kilometers (155 miles) from the Martian surface, *Rosetta* slipped into the cold, dark shadow of Mars. The radio signal would be gone for 15 minutes, and getting it back on time would indicate that the spacecraft was healthy and surviving eclipse well. It would be an additional 10 minutes before *Rosetta* was back in its natural habitat, with the Sun warming its solar arrays.

Enjoying the Scenery (While Biting Our Nails)

The highlight of the flyby for a space enthusiast like me, however, was not the illustration of celestial driving but the opportunity to see the stunning imaging, remote sensing, and science by *Rosetta* and its lander, *Philae*.

While the craft was out of touch with the ground, OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) Principal Investigator Uwe Keller showed the assembled press representatives at ESOC some preliminary images. OSIRIS is a pair of four-megapixel optical cameras on board *Rosetta*, one wide angle and one narrow angle. OSIRIS was to play just one part in an intense science campaign that began nine hours before closest approach and extended many hours after it. In addition to OSIRIS's visible image data, the ultraviolet imaging spectrometer, Alice, captured ultraviolet data, and VIRTIS (the Visible Infrared Thermal Imaging System) observed Mars in the infrared.

We would have to wait a while for results from Alice and VIRTIS, but an early OSIRIS image of Mars from a range of 240,000 kilometers (144,000 miles) showcased the fantastic imaging capability of



This amazing view was captured by the CIVA camera on Rosetta*'s* Philae *lander four minutes before its closest approach to Mars, on February 25, 2007. The spacecraft was only 1,000 kilometers (600 miles) above the planet. Part of the spacecraft bus fills the view on the left side, and one of the long solar panels stretches out across the center. In the background is the globe of Mars, the view centered near Syrtis Major.* Image: *CIVA/*Philae*/ESA* Rosetta

the OSIRIS system. At face value, it's a beautiful picture of Mars, and a closer look reveals some fascinating details. The most astonishing is the cross section–like view of the atmosphere on the right-hand limb, where—especially at the top right and bottom left—high-altitude clouds can be seen "edge on" about 50 to 60 kilometers (30 to 36 miles) above the surface. Toward the bottom left are early morning clouds being burned away by the Sun, and near the equator, right of center, is a crater with a "tail"—Gusev crater, where Mars rover *Spirit* is quietly trundling around.

Success! And Data to Commemorate the Occasion

"A bit less than one minute to get the signal back. . . . 15 seconds away." Wow . . . 15 seconds can take what seems like hours, but right on time, Montagnon announced, "We have S-band secure indication of the end of occultation." Andrea Accomazzo, *Rosetta* spacecraft operations manager, told us that having the signal back on time meant that the spacecraft was healthy and had survived the first 15 minutes of eclipse. If the spacecraft had not been healthy, it would have turned off its transmitter.

Another 10 minutes of eclipse remained, so the tension continued. Keller attempted to lighten the atmosphere by joking, "'I'm so cold, I'm so cold' . . . said the spacecraft." I chuckled quietly but stopped when I realized no one else found the concept of the spacecraft freezing to death quite so funny.

Again, right on time, Accomazzo ended our wait by telling us that the spacecraft had come out of eclipse. We knew that it was healthy and the flyby was a perfect success. "Now we can all sleep," he said. And so we did. At 5:00 a.m., I walked out of the cold, dark park of office buildings to get a taxi back to the hotel for a little sleep and to wait for more pictures.

New images arrived 12 hours later, and the true star of the *Rosetta* flyby made itself known. The surprise element was the lander, *Philae*, destined to land on and study comet Churyumov-Gerasimenko. For now, however, *Philae* remains firmly attached to the side of its parent spacecraft. As an entirely independent spacecraft, it was designed to survive darkness, as it will experience both day and night at its landing site on the cometary nucleus. This meant that for a total of three hours—including the 25 minutes of the eclipse—*Philae* was operating independently of *Rosetta*, powered up on its own batteries and doing science on its own. During the flyby, two of its instruments took data: its camera system, CIVA, and the *Rosetta* lander Magnetometer and Plasma monitor, ROMAP.

ROMAP measured the magnetic field around Mars as it flew through the lumpy Martian magnetic field. It was CIVA, however, that stole the show. Just four minutes before closest approach at a distance of 1,000 kilometers (600 miles), one of the five cameras that makes up the CIVA package captured an amazing image of the back of a solar array, with an ochre-colored Mars below.

Downlink of flyby science will continue until the end of March, and some unique science results will surely follow, but this one spectacular frame will serve as a reminder of a brief encounter early on a February morning 315 million kilometers (189 million miles) from home.

Doug Ellison is the host of unmannedspaceflight.com. *He covered the* Rosetta *flyby event for The Planetary Society's weblog at* planetary.org/blog.

"Once in a while, we do something right in Europe. We chose over 20 years ago to target a flyby of Halley, which we called *Giotto* . . . it was Europe first declaring it could do things in the solar system. We lay fallow for quite a few years, but in the last few years I think it's fair to say Europe's back in the solar system. We've been to the Moon, to Mars, to Venus, and, with enormous help from the Americans, we went to Titan, but, happily, I think we're going back to a comet. This is back to the beginning again, and it's back to the beginning of the solar system. I don't have any concern or any guilt about spending public money this way—really it's a duty."
—David Southwood, ESA's Director of Science

World Watch

by Louis D. Friedman

Washington, D.C.—In an event unprecedented in my experience, the U.S. Congress received the administration's proposed budget for fiscal year 2008 (starting in October 2007) before it had passed the FY 2007 budget. The Congress did not give final budget approval for 2007 until February, five months into the fiscal year.

NASA's 2008 budget proposal was much like the one proposed for 2007—a 3 percent total increase, with emphasis on keeping the new human spaceflight vehicles, *Ares* and *Orion*, on schedule to replace the space shuttle. This emphasis on the rockets' schedule came at the expense of NASA's science and exploration budget. Work has stopped on new robotic missions, such as a Europa orbiter, a Mars sample return, and *Terrestrial Planet Finder*, while research and data analysis were cut, with astrobiology down 50 percent.

We hoped that Congress was going to fix things partially with the 2007 budget; both the House and Senate Appropriations Committees had been working toward adding funds for science. The Republican Congress adjourned last year without passing a budget, however, and the new Democratic Congress wanted no part of last year's work. Instead, it reset all the 2007 levels to those of 2006—which meant that NASA received less than it had planned on. Congress did tell NASA not to cut more from science, but it let the administrations' proposed cuts ride. Therefore, the schedules for developing *Ares* and *Orion* will slow, and plans for a planned robotic lunar lander will be delayed indefinitely.

We hope Congress will now consider the 2008 budget proposal more quickly and completely than it did last year's budget. The Planetary Society will continue the fight to restore science funding and lost missions.

In a new development, the National Research Council released its long-awaited report on observing Earth from space, which warned that we face a decrease in our ability to monitor our own world if proposed decreases in programs run by NASA and the National Oceanic and Atmospheric Administration are allowed to stand. This year's Save Our Science campaign will emphasize the strong synergy of exploring other worlds and the importance of observing Earth as a planet.

Vienna, Austria—In February, our International Lunar Decade (ILD) proposal was enthusiastically received by the U.N.'s Committee on the Peaceful Uses of Outer Space technical subcommittee. The approximately 100 delegates from many nations appreciated the role that space exploration can play in inspiring hope for the future.

The ILD fit into the agenda as part of the International Heliophysical Year (IHY) of 2007. Some 70 nations are participating in the IHY, which covers all physical processes "under the Sun." The next step is for national space agencies to consider the ILD as they plan international coordination and cooperation on lunar missions.

The Moon—One of the casualties of the 2007 budget is the cancellation—or indefinite deferment—of robotic lander missions that were to precede the return of humans to the Moon. The only robotic lunar mission now in the works is the *Lunar Reconnaissance Orbiter* and its accompanying LCROSS (Lunar CRater Observation and Sensing Satellite) impactor, planned for 2009.

NASA did institute a new line item for lunar science, providing funding for scientists to work on landers planned by other nations. This is a small victory for the Society—we have urged international cooperation in lunar missions. Fourteen space agencies are now in the midst of a series of meetings on international cooperation in space. In March, representatives met in Kyoto, Japan; in May, they will meet in Spineto, Italy to consider a framework for such cooperation.

In other Moon news, China appears to have delayed its planned launch of *Chang'E* to the second half of 2007. The Japanese space agency is on schedule to launch its *SELENE* mission this summer.

Moscow, Russia—Reports from Russia indicate that funding to the Russian space agency, ROSCOSMOS, has increased, and missions to the Moon and Mars are again under consideration. Most immediate is a Phobos soil sample return mission (in Russian, it is called *Phobos Grunt*), being planned for a 2009 launch. Russian space scientists have wanted to go back to this moon of Mars since the untimely end of their Phobos rendezvous in 1989. That mission made many remote observations of Mars and Phobos but was lost before its lander could be deployed on the surface.

Lunar Glob (globe), a mission to orbit the Moon and possibly deploy penetrators in the 2011–2012 time frame, is also being planned.

Oil revenues have boosted the Russian federal budget, and increased funding for the space agency has encouraged leaders in the human spaceflight program to build their *Klipper* orbital tug and even to dream again of sending cosmonauts to the Moon. But it will be the Phobos sample return mission that will prove whether or not Russia is back as a major player in space exploration.

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

Europe's First Trip to Mars

BY A.J.S. RAYL

This mosaic of High Resolution Stereo Camera images shows a large depression called Iani Chaos and the upper reaches of a large outflow channel called Ares Valles. Mars Express' camera took the images composing this mosaic during three orbits from an altitude of 350 kilometers (210 miles). The Iani Chaos depression—180 kilometers (110 miles) long and 200 kilometers (120 miles) wide—is connected to the beginning of Ares Valles by a transition zone about 100 kilometers (60 miles) wide. From here, Ares Valles continues its course for about 1,400 kilometers (840 miles) through the ancient Xanthe Terra highlands and eventually empties into Chryse Planitia.
Image: ESA/DLR/FU Berlin (G. Neukum)

The proposal was daring and romantic: Europe's first mission to another planet would send both an orbiter and a lander to Mars in 2003 to study the planet from the top of its atmosphere to below the surface, searching for water and signs of life for at least one Martian year (687 Earth days).

The plan was as practical as it was ambitious. The mission would be the first in a series of "express" ventures developed more quickly than typical large NASA missions—faster, better, cheaper, with technologies that would transfer to future missions. *Mars Express* would be the first mission to take scientists thousands of meters beneath the surface of the Red Planet with state-of-the-art radar and the first recent mission to carry instruments designed to look specifically for life, past or present.

At a projected cost to the European Space Agency (ESA) of 165 million Euros, it seemed almost too financially reasonable, even though the instruments were to be developed and financed independently by member countries. There was also the fact that Europe's primary claim to fame in space exploration was its mission to Halley's comet in 1985, as well as the reality that more spacecraft headed to Mars have failed than succeeded. On the plus side, Europe had the one asset it needed: desire.

Mars Express quickly won the approval of ESA's member states in 1997. The mission underwent a number of modifications, each of which—including unplanned aid to the *Beagle 2* lander team—added to the final price tag of about 200 million Euros. But the dream lived, and *Mars Express* somehow made its planned launch window. On December 25, 2003, Europe's sparkling spacecraft arrived at Mars, a Christmas gift the likes of which the continent had never known.

"Just five years ago, we were viewed by many as a flash-in-the-pan called *Giotto*," mused ESA's Director of Science David Southwood during an interview with *The Planetary Report*. In the past three years, however, *Mars Express* has assumed its place in the elite club of successful Martian missions. It has returned textbook-changing data and inspired future European pursuits, including a rover mission called *ExoMars*, which is set to look for life in 2013. "You might say," Southwood offered with a smile, "the Empire has struck back."

Mars Express was launched on June 2, 2003, aboard a Soyuz rocket from Baikonur, Kazakhstan. It carried

seven science instruments and the United Kingdom's lander. Named for the expeditionary ship that ferried Charles Darwin to the Galapagos, *Beagle 2* was to search for signs of extraterrestrial species on the surface of Mars.

As the spacecraft neared the Red Planet more than six months later, *Beagle 2* separated from the mothership to coast for five days, then enter the Martian atmosphere. It was scheduled to land Christmas morning and signal with a riff from a rock song. Anticipation was global. *Beagle 2* and its "father," Principal Investigator Colin Pillinger of the Open University, had captured hearts around the world. But no signals were ever heard. In January 2004, the "puppy" was declared lost. Although *Beagle*'s silence left many grieving that day, ESA's mothership pressed on.

Just hours later, *Mars Express* slipped into orbit flawlessly, and the world cheered.

On its way to Mars,* Mars Express *carried with it the* Beagle 2 *lander. The lander separated from the orbiter on December 19, 2003 and began its journey to the Martian surface. The first radio contact with* Beagle 2 *was expected on December 25, but no signal was ever received.
Illustration: ESA/Denman Productions

Unlocking Clues to Past Water

Even before *Mars Express* reached its final science orbit at the end of January 2004, the mineralogical mapping spectrometer—known as OMEGA (Observatoire pour la Mineralogy, l'Eau, les Glaces et l'Activité)—confirmed the presence of vast fields of perennial water-ice stretching out from Mars' south pole, contributing to the ever-evolving story of water on the Red Planet.

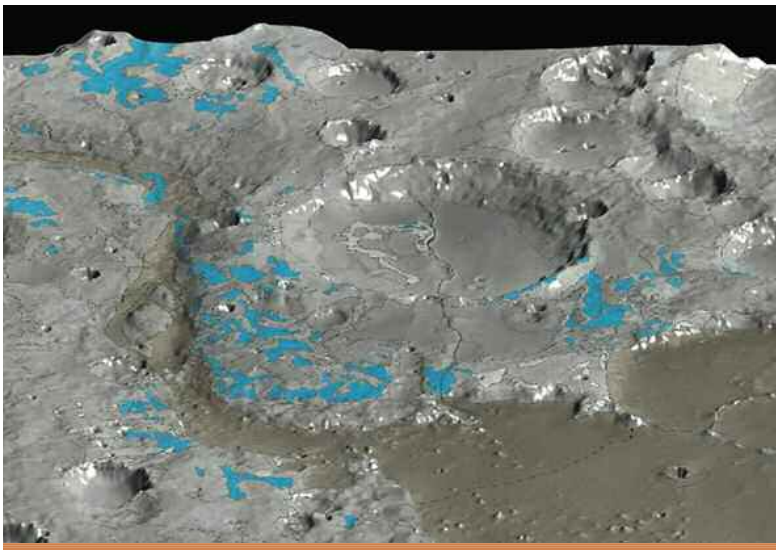
OMEGA went on to uncover hydrated sulfate salts in various areas around the planet's surface, findings that support the Mars Exploration Rover *Opportunity*'s discovery that the Meridiani Planum area of ancient Mars had liquid water on or immediately beneath the surface.

Then, at the American Geophysical Union (AGU) meeting in December 2005, OMEGA scientists announced their discovery of evidence of past water on Mars' surface in deposits of clay minerals and other phyllosilicates. The data revealed the presence of hydrated surface minerals that contain water in their crystalline structure, according to Principal Investigator Jean-Pierre Bibring.

OMEGA detected the clay minerals, known to form during long-term exposure to water, only in the oldest regions of Mars. That led the team to hypothesize that any large bodies of standing water were gone within half a billion years of the planet's formation; they either disappeared from the surface by seeping underground or were lost into space. During the evaporation process, sulfates were created, and when this process naturally concluded and the remaining water became permanently frozen, the atmosphere gradually turned the soil red by creating another mineral the instrument detected: ferric oxide.

From the discovery of these minerals and their locations, Bibring and some of his colleagues hypothesized, controversially, that Mars has undergone three distinct geologic eras and concluded that the planet became a cold, dry, hostile environment a long, long time ago. It is possible the clay beds formed underground by another mechanism, such as vulcanism or, perhaps, the natural cooling of the planet. If that's the case, "the surface conditions may always have been cold and dry," Bibring said.

Either way, the identification of these clay beds on Mars provides high-priority targets for future landers looking for evidence of life, because where there is liquid water on Earth, there is life. "If living organisms formed, the clay material would be where this biochemical development took place," he reasoned. "And the cold Martian conditions could have preserved most of the record of biological molecules up to the present day."



The OMEGA instrument on board ESA's* Mars Express *has mapped the water-rich minerals (blue) in this HRSC 3-D perspective view of the Marwth Vallis area on Mars. Scientists have not detected hydrated minerals or sediments, either in the channel or in its opening; however, erosion from a violent outflow event in this area exposed ancient, hydrated, clay-rich minerals from an earlier era when water was present. *Image: ESA/OMEGA/HRSC*

The clay beds observed by OMEGA once could have supported the development of life, making them exciting sites for future Mars rovers to explore. The background image shown here is an HRSC perspective false-color view of the Mawrth Vallis region on Mars with an artist's impression of a possible future rover superimposed.

Image: ESA/OMEGA/HRSC

Where Did the Water Go?

What happened to all the water that once flowed across the surface remains one of the biggest Martian mysteries. To help unravel that mystery and to find out how strongly the interplanetary plasma and electromagnetic fields affect the Martian atmosphere, one team of *Mars Express* scientists is taking measurements with ASPERA-3 (the Analyzer of Space Plasma and Energetic Atoms). The measurements reveal how the solar wind (the stream of ions and electrons racing outward from the Sun) interacts with the Martian upper atmosphere and the planetary wind (the outflow of particles from the atmosphere and ionosphere).

ASPERA-3 scientists use a technique known as *energetic neutral atom imaging* to visualize the charged and neutral gas environments around Mars and can thus actually see plasma escaping the planet. By measuring ions, electrons, and energetic neutral atoms in the outer Martian atmosphere to find the number of oxygen and hydrogen atoms (the constituents of water) that interact with the solar wind, the scientists can observe the slow, "invisible" escape of volatile gases and liquid compounds that make up the atmosphere and hydrosphere of a planet. The data from this solar wind "scavenging" allow the estimation of how much water the planet would have lost over its 4.5 billion years at the current rate of loss.

In its first year, ASPERA-3 confirmed that a very efficient process is at work in the Martian atmosphere, one that could help resolve the mystery of the missing water. Mars no longer has a global magnetic field to deflect the solar wind, so the deluge of charged particles from the Sun is free to interact with atoms of atmospheric gas and sweep them out to space. ASPERA-3 Principal Investigator Rickard Lundin and colleagues found that the solar wind penetrates Mars' ionosphere deeply into the atmosphere, down to an altitude of 270 kilometers (160 miles). They suggest this may be the reason for the acceleration processes that cause the significant loss of atmosphere on Mars and probably was a key factor in the loss of a lot of water from the planet some 3.8 billion years ago, assuming the magnetic field was as low then as it is today.

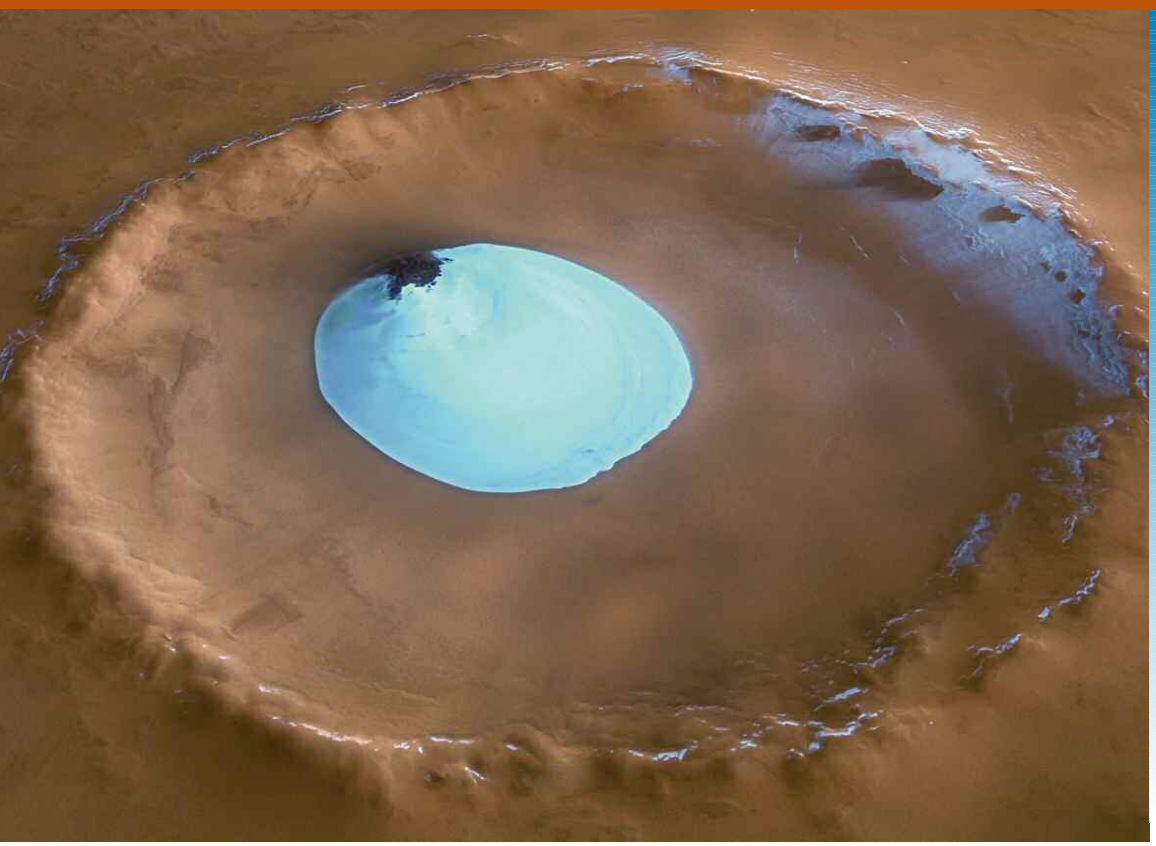
A Keen Eye on Mars

Amid all the new data are High Resolution Stereo Camera (HRSC) pictures that reveal the Martian topography in exquisite detail. The camera has returned a bounty of breathtaking views never before shot, from an orbit of 260–300 kilometers (160–180 miles). Originally developed for the Russian *Mars '96* mission, the updated HRSC features unprecedented pointing accuracy, which is achieved by combining images at two different resolutions and the capability to image in 3-D.

By late winter of 2007, the HRSC had imaged 35 percent of Mars' surface in stereo and in color at a resolution of 10 to 20 meters. "By the end of 2007, we will have achieved approximately 50 percent," said HRSC Principal Investigator Gerhard Neukum. His team has also used the HRSC to take selected close-ups of chosen areas at a two-meter resolution, allowing scientists to pick out "great detail" on the surface.

The HRSC data are aiding in the "follow the water" quest, offering visual support for OMEGA's findings and adding to the increasing body of evidence pointing to bodies of liquid water in Mars' distant past. The pictures of Kasei Valles, one of the biggest outflow channel systems on Mars, for example, indicate this feature was carved by a gigantic Martian glacier that persisted for a billion years, when the temperature of Mars had dropped too low for liquid water to flow across the surface.

The HRSC has also returned compelling pictures of volcanic areas at the north pole, where cliffs more than a kilometer high encompass fields of dark volcanic ash, and of other fields with cones up to 600 meters tall that hint of fairly recent volcanic activity. These images helped lead the team to propose that there is a link between volcanic regions and water flows. It appears that when volcanic activity occurred



A bright patch of residual water-ice sits in this unnamed impact crater located in Vastitas Borealis, a broad plain that covers much of Mars' far northern latitudes. The crater is 35 kilometers (22 miles) wide and has a maximum depth of approximately 2 kilometers (about 1 mile). The ice patch is present all year round. **Mars Express*' HRSC obtained this perspective view in February 2005. The colors are very close to natural, but the vertical relief is exaggerated three times.***
Image: ESA/DLR/FU Berlin (G. Neukum)

on Mars, it melted ice and heated water deep inside the planet, which then flowed to the surface. It is intriguing that some of these flows are recent, at least in geologic terms—within the last 30 million years, according to Neukum.

Other HRSC images have revealed current residual patches of frozen water, homing in on water-ice at the planet's south pole and even a frozen expanse of water. At ESA's *Mars Express* conference in March 2005, scientists announced they had found a five-million-year-old frozen sea near the planet's equator on the flat, dust-covered plain known as Elysium Planum. John Murray and colleagues reported a geographic feature that looks something like an Antarctic ice pack measuring 810 by 900 kilometers (500 by 560 miles), covered by a layer of volcanic ash that has kept it from evaporating. The images will be scrutinized by future mission leaders looking for scientifically rich landing locations, if only because it is remotely possible that the first Martian life to be found made or makes ice its habitat.

Looking Beneath the Surface

The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) instrument is finding other choice sites for future rovers to explore as it characterizes the surface and searches for signs of water and geologic formations below the surface. The first sounder and "the only instrument designed to investigate the surface and the subsurface of another planet," as MARSIS Principal Investigator Giovanni Picardi describes it, the radar looks for water by picking up reflections of radio waves in the upper 4–5 kilometers (2.5–3 miles) of Martian crust using techniques similar to those used in oil prospecting on Earth.

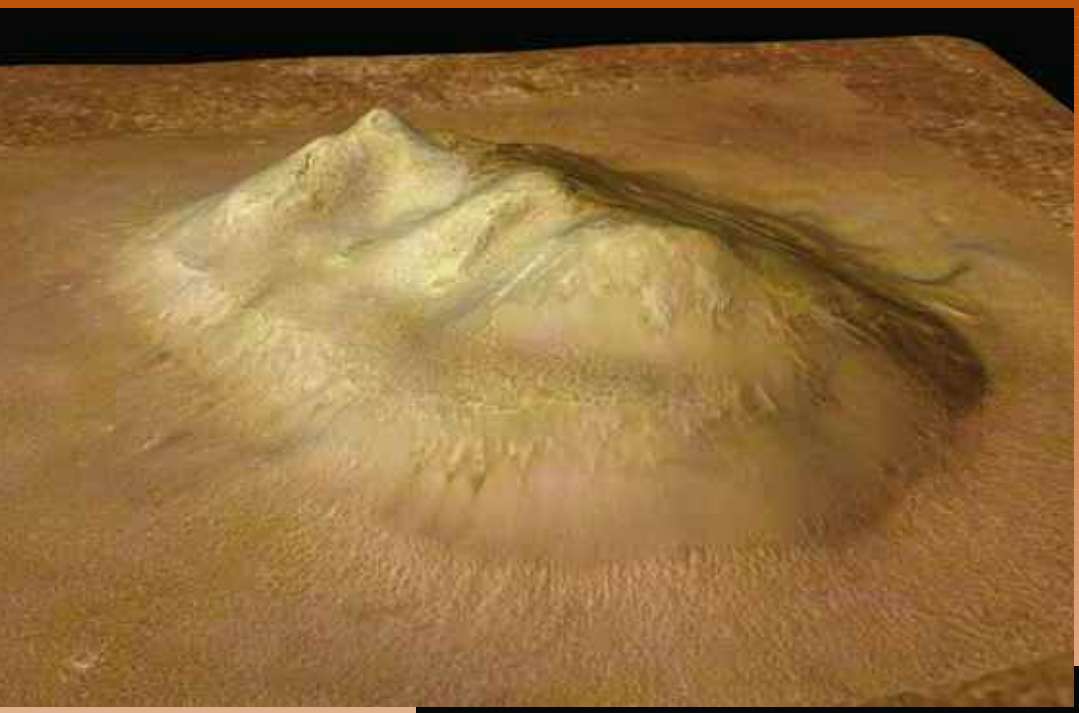
MARSIS uses the reflections to map the distribution of water and ice in the upper portions of the crust, which scientists then interpret as subsurface structure. Deployment of the radar's three antennas was delayed by about a year for safety reasons, but within days of the instrument's checkout in June 2005, the radar vicariously took scientists thousands of meters beneath Mars' surface to look for ice, water-ice, permafrost layers, and liquid water.

When the spacecraft passed over the northern lowlands in the Chryse Planitia region at Mars' midlatitudes, MARSIS uncovered a buried impact crater at a shallow depth of 1.5 to 2.4 kilometers (0.9 to 1.5 miles). Inside this circular structure, about 250 kilometers (150 miles) wide, is a thick layer of material rich in water-ice. Previous observations revealed water-ice in the area, but MARSIS data suggest that this is a rather large chunk—1.8 kilometers (1.1 mile) thick. When the radar probed the layered deposits that surround the north pole of Mars, it detected what scientists believe is a nearly pure water-ice layer thicker than 1 kilometer (0.6 mile) over a deeper layer of basaltic regolith.

"We are finding reservoirs of ice that have never been seen before," Jeffrey Plaut, co-principal investigator, noted. "But we are still puzzling out when and where the water on Mars was liquid."

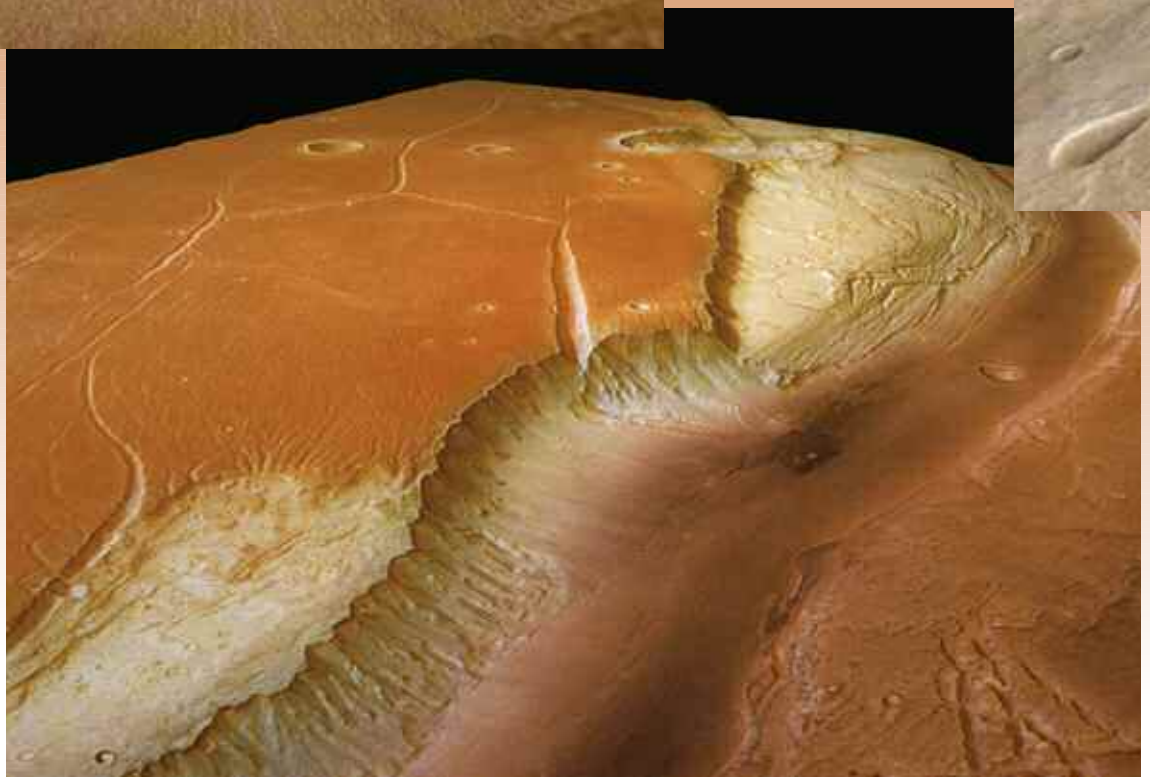
Methane on Mars—What Does It Mean?

Although *Beagle 2* didn't survive, *Mars Express*' Planetary Fourier Spectrometer (PFS), within weeks



Left: Mars Express *turned its focus toward the popular and controversial Cydonia region, site of the "face on Mars" first imaged by NASA's* Viking 1 *in 1976. This HRSC perspective view shows the so-called face on Mars with new detail. The famous formation is actually a remnant plateau thought to have been created by landslides and an early form of debris apron formation.*

Image: ESA/DLR/FU Berlin (G. Neukum) and MOC (Malin Space Science Systems)



Right: Kasei Valles—one of the biggest outflow channel systems on Mars—was likely formed by gigantic flood events and later shaped by glacial activity. This HRSC perspective view of the northern branch of Kasei Valles looks to the west (the image has been rotated approximately 90 degrees clockwise so that north is to the right).

Image: ESA/DLR/FU Berlin (G. Neukum)

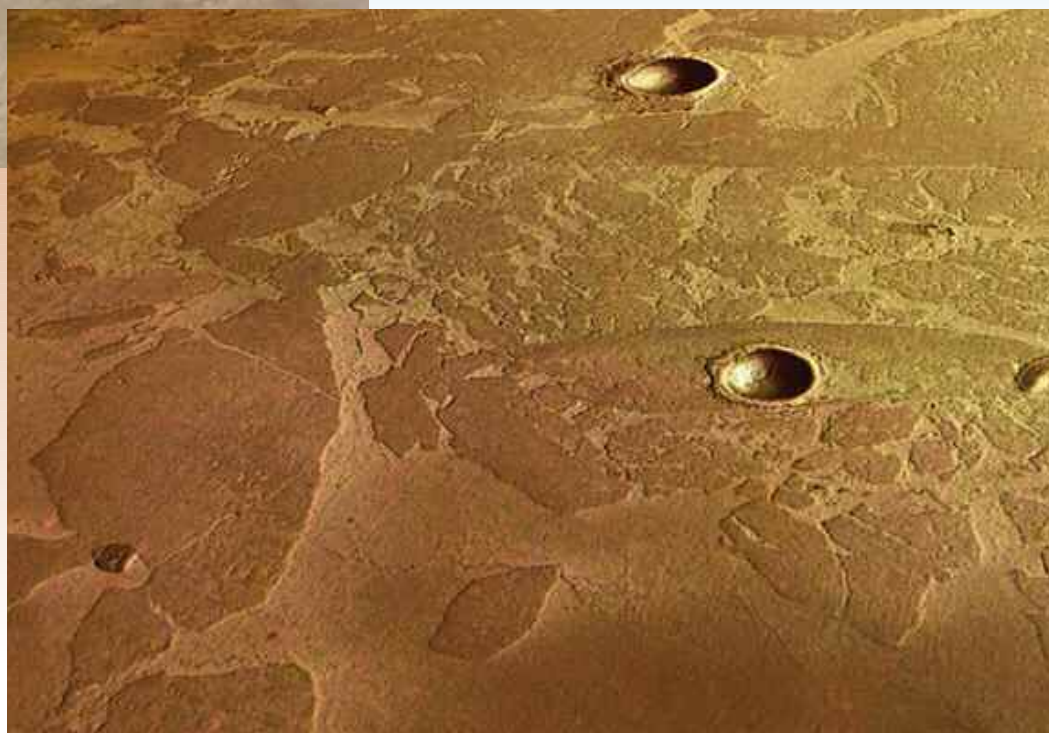
of arriving at the Red Planet, found possible signatures of constituents in the atmosphere that could be emanating (theoretically) from some source of biological life.

The PFS looks at the global atmospheric distribution of both major and minor constituents with accuracy greater than any previous mission. It measures the vertical pressure and temperature profile of carbon dioxide, which makes up most of the Martian atmosphere, while also monitoring for minor constituents, such as water, carbon monoxide, ammonia, methane, or formaldehyde.

The PFS made headlines in March 2004 when it became the first instrument to make direct measurements of methane in the atmosphere of Mars. The discovery was confirmed independently around the same time by two ground-based experiments. Subsequently, PFS Principal Investigator Vittorio Formisano reported concentrations of methane and water vapor in the atmosphere above Elysium Planum. He also found signatures that appeared to be from formaldehyde and ammonia.

The methane could be produced by some sort of geologic outgassing, but Formisano has been leaning toward the theory of a biologic origin. As he pointed out, even Earth volcanism, which is more active than on Mars, would not account for the 10 parts per billion of methane in the atmosphere that his team is finding (and which the two ground-based teams also reported). If methane, formal-

Left: Researchers believe the features in this image are lava tubes, channels formed by hot, flowing lava that form a crust as the surface cools. Lava continues to flow beneath this hardened surface, but when lava production ends and a tunnel empties, the surface collapses, forming an elongated depression. HRSC captured these lava features on the southwestern flank of Pavonis Mons, the central volcano of the three shield volcanoes that constitute Tharsis Montes. The long, continuous lava tube in the northwest of the image extends more than 59 kilometers (35 miles) and ranges from approximately 1.9 kilometers (about 1 mile) to less than 280 meters wide. *Image: ESA/DLR/FU Berlin (G. Neukum)*



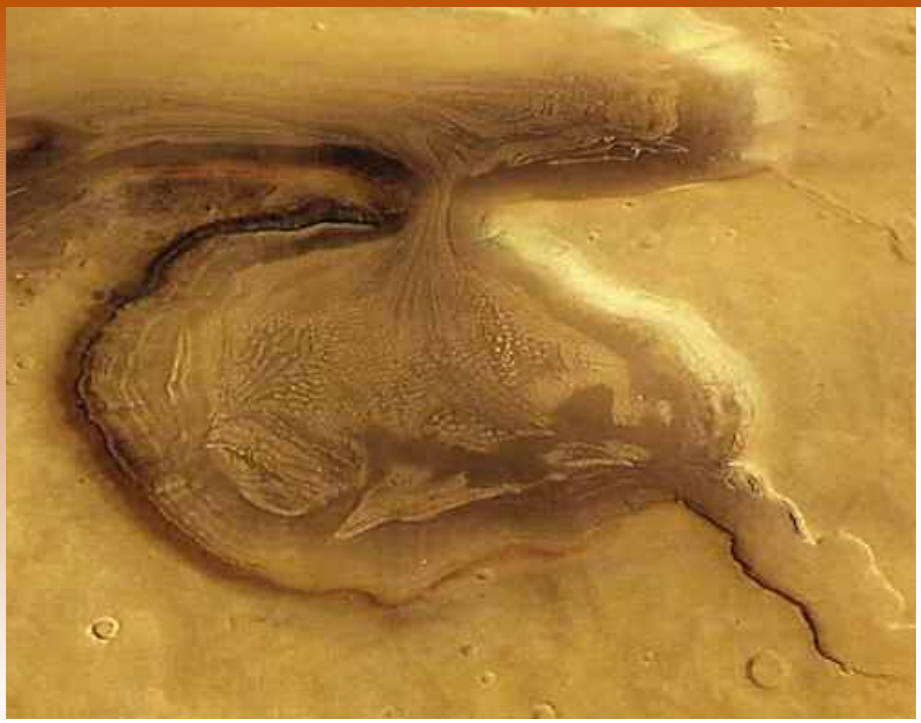
Right: Is this a dust-covered frozen sea near the Martian equator? The HRSC team suggests that it is. The team hypothesizes that water rushed out in a catastrophic flood that collected in a vast flat area in Elysium Planitia. As the water began to freeze, floating ice broke into rafts, which were later covered in volcanic ash and dust that protected the ice from subliming. Scientists cannot yet determine if the ice is still there or if the landforms are just fossils of the previously existing pack ice.
Image: ESA/DLR/FU Berlin (G. Neukum)

dehyde, and ammonia are confirmed to be in the atmosphere and emanating from the same area, the combination could bolster the case for biologic origin or a source unknown on Earth. The signatures of formaldehyde and ammonia, however, have not been shown unequivocally and therefore are controversial. The team continues to take measurements.

Strange Auroras and CO_2 Clouds

As the search for water and signatures of life continue in studies with MARSIS, HRSC, OMEGA, PFS, and ASPERA-3, the mission is also opening new windows on Mars' atmosphere and ionosphere. SPICAM (Spectroscopy for the Investigations and the Characteristics of the Atmosphere on Mars) is a dual ultraviolet/infrared spectrometer that measures the composition of the atmosphere over smaller volumes than does the PFS. Using the technique of stellar occultation, the SPICAM team is also measuring the vertical profiles of carbon dioxide, temperature, ozone, aerosols, and clouds.

In June 2005, SPICAM Principal Investigator Jean-Loup Bertaux and his team announced the first discovery of an aurora on Mars. The midlatitude aurora—unlike any ever seen in the solar system—appeared to be corresponding to a paleomagnetic signature or remnant of Mars' former magnetic field. The anomalistic fields were nearly



***Since the* Viking *missions of the 1970s, planetary scientists have changed their perception of water on Mars several times—from the picture of a dry planet to that of a warmer and wetter one.* Mars Express *data are now shedding new light on the complex issue of the evolution of water on the Red Planet. This image, taken by HRSC on board* Mars Express*, shows a perspective view of a glacial feature located in Deuteronilus Mensae in the northern plains of Mars.** Image: ESA/DLR/FU Berlin (G. Neukum)

The high-altitude cloud layer has implications for landing on Mars because it suggests that the upper layers of Mars' atmosphere could be denser than previously thought. This is important information for future orbiters that aerobrake (use the friction in the outer atmosphere to slow an orbiting spacecraft) or future lander missions. If *Beagle 2* had such information, its fate may well have been different.

as strong at the surface as Earth's magnetic field and were laid out in east-west bands of alternating polarity, extending for more than 1,000 kilometers (620 miles) north to south.

According to *Mars Global Surveyor* (*MGS*) data, the strongest magnetic anomalies on Mars are related to Terra Cimmeria and Terra Sirenum in the heavily cratered uplands of the southern hemisphere. In analyzing the map of crustal magnetic anomalies compiled with *MGS* data, SPICAM team members observed that the region of nighttime light emissions (corresponding to 177 degrees east and 52 degrees south) is right where the strongest magnetic field is localized. The SPICAM observations will help in defining the role that the Martian crustal magnetic fields play in producing these distinctive, cusp-like magnetic structures, which concentrate fluxes of electrons into small regions of the atmosphere and catalyze the formation of highly concentrated auroras.

In August 2006, the SPICAM team announced another discovery: the highest clouds observed on Mars. At an altitude between 80 and 100 kilometers (50 and 60 miles), where the temperature is around –193 degrees Celsius (–315 Fahrenheit), the clouds are presumed to be composed of carbon dioxide.

SPICAM made the discovery by observing distant stars just before they disappeared behind Mars. They looked at the effects on the starlight as it traveled through the Martian atmosphere and built up a picture of the molecules at different altitudes. The first hints of the new cloud layer came when certain profiles or "sweeps" through the atmosphere showed that the star dimmed noticeably when it was behind the atmospheric layer. Although this happened in only one percent of the profiles, by the time the team had collected 600 profiles, they were confident the effect was real.

Examining the Ionosphere

In addition to looking below the surface of Mars, MARSIS also has been used to examine the upper part of the atmosphere. It has revealed a complex structure in Mars' ionosphere and found a number of unexpected features, according to Principal Investigator Picardi. Team members are analyzing the data to explore the connection between the ionosphere's structure and the behavior of remnant magnetic fields that permeate the crust of the Red Planet.

When comparing the MARSIS map with maps of the Martian crustal magnetic field from *MGS* data, MARSIS scientists realized that their findings corresponded to areas of strong magnetic fields in the crust of the planet. The crustal magnetic fields cannot account for all the distinctive echoes MARSIS observed, even if they are responsible for the majority of them. Therefore, the team is investigating other possible mechanisms for the production of these echoes, including wind-driven atmospheric waves excited by topographic features and various types of wavelike structures in the atmosphere caused by interaction with the solar wind.

MaRS, the radio instrument on which *Mars Express* relies to communicate with Earth, is also being used to study the atmosphere and ionosphere of the planet. By measuring local variations in gravity over the surface of the planet and providing pressure and temperature profiles of the atmosphere, MaRS found a third, noncontinuous layer in the ionosphere that had been predicted but never before detected.

During two *Mars Express* occultation seasons—April to August 2004 and December 2004 to January 2005—MaRS detected the presence of regions in the atmosphere where the density of charged particles (electrons) was about one tenth the density of the

As* Mars Express *enters eclipse around Mars, it flies in a survival-mode configuration nicknamed* Sumo. *In this artist's illustration,* Mars Express *is shown in a power-saving warm-up attitude, with its base pointed toward the Sun to catch the most heat.

Illustration: ESA/Celestia

main ionospheric layer. MaRS Principal Investigator Martin Pätzold and colleagues reported that these regions, localized between 65 and 110 kilometers (40 miles and 68 miles) altitude, "unambiguously characterized the third ionospheric layer below the first two," which are respectively situated at 135 kilometers and 110 kilometers (84 miles and 68 miles) altitude. Because MaRS observed these higher-density regions only in a few ionospheric areas, the team concluded that this third layer is sporadic and geographically localized.

"We favor the idea that the third layer is created by the influx of meteors, like on Earth," Pätzold said in November 2005. On Earth, however, the low ionospheric layer is nonsporadic and created by electrical charge exchange between the atmosphere and magnesium and iron atoms present in meteors. Because the atmosphere is thinner and less dense on Mars, meteors require more kinetic energy to exchange charged particles above 75 kilometers (45 miles) altitude, where the Martian atmosphere becomes really thin. "The population of meteors with this energy is more limited," Pätzold pointed out. "This could explain the sporadic occurrence of the third ionospheric layer on Mars."

Mars Express Orbits On

From the top of Mars' atmosphere to below its surface, *Mars Express* has delivered on its promises and made discoveries with each of its scientific instruments.

"The HRSC is showing us geological processes on Mars, such as volcanism, that may be much younger than people previously thought," *Mars Express* Project Scientist Agustin Chicarro offered by way of summary. "OMEGA has written a history of Mars in more detail, and a chronology of the alteration of minerals on the surface. ASPERA-3 is telling us how the water leaves the planet. SPICAM has shown the existence of auroras that were totally unexpected and completed full profiles on density and temperature of the atmosphere. The PFS discovery of methane could lead to something important concerning life on Mars, if we could confirm the results. MARSIS has shown delicate layering in the polar regions and buried impact basins in northern plains that indicate all of Mars has the same scars of the early bombardment. That means the whole of Mars is a pretty old surface. Radio science is finding interesting things like the third transient layer in the ionosphere, and the gravity profiles that are rather unique are like the cherries on the cake, because they provide additional information to all the other fields we are studying."

More discoveries are no doubt in the offing. On February 23, 2007, ESA's Science Programme Committee unanimously approved funding for an extension to May 2009. So *Mars Express* will orbit on, longer than anyone dared believe in 2003.

"This is the first European planetary mission ever and we're all a little surprised," Chicarro said, then paused to reflect. "With every big mission to Mars, it seems more is gained than incremental knowledge. Now with *Mars Express*—and the Mars Exploration Rovers to provide ground truth—we are taking the next step, and we are rewriting the history of Mars."

A.J.S. Rayl is a journalist and regular contributor to The Planetary Society's website, planetary.org.

Annual Report To Our Members

Dear Planetary Society Members, Donors, and Friends,

Last year at this time, The Planetary Society had just celebrated its 25th anniversary and embarked upon what we call "our next age of exploration." So where have we arrived at the end of the first year? Here is a flyby of key events that shaped 2006 and that lie ahead in 2007.

With you—members and supporters on seven continents—we have entered an age of exploration marked by contradiction. On one hand are seemingly endless possibilities for exploration and discovery, and on the other, perilous cuts to funding for space science that threaten to extinguish those very possibilities.

Save Our Science (SOS)

In the face of public enthusiasm for space exploration fueled by the success of recent missions, NASA cut its budget for space science. The Planetary Society responded with a campaign to Save Our Science.

We took our SOS campaign to Washington, D.C. in May, where, at the invitation of the U.S. House Science Committee, *Titanic* director James Cameron, Society Vice President Bill Nye the Science Guy, planetary scientist and Society board member Heidi Hammel, and Executive Director Louis Friedman exhorted congressional staff to understand and embrace the value to their constituents of space science and planetary exploration.

We presented petitions, signed by 5,000 Society members and supporters, to the House and Senate Appropriations Committees and later to President Bush, urging them to restore science funding. But today, we are still fighting budget cuts that threaten space science even as we are presented with its extraordinary discoveries.

New Horizons

Putting proof to the power of our members' voices and their long, successful campaign to save a mission to a beloved ball of ice and rock, the *New Horizons* spacecraft set forth in 2006 on its nine-year journey to Pluto. With it went the Society's Digital Time Capsule—50 images, culled from submissions from 40 countries, depicting what may change by the time the spacecraft arrives in 2015.

Are We Alone?

Funding cuts have not deterred the Society and its members from making innovative projects possible, and so it was that I proudly attended the springtime opening of The Planetary Society's Optical SETI telescope.

Funded by the Society, the Harvard University–operated telescope is dedicated to capturing that pulse of light that might be a communication. It will scan the Northern Hemisphere, and in a single second it will crunch more data than are stored in all the books in print.

Paving the Way with Planetary Analogs

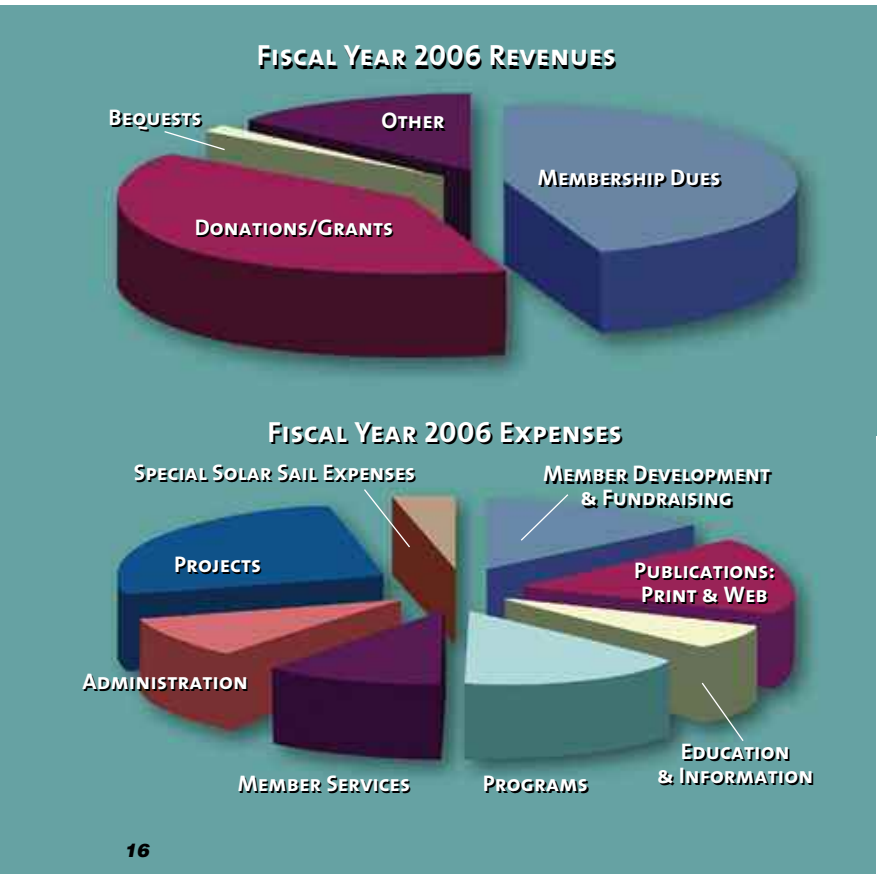
The Society seized opportunities in June and August to help fund expeditions to study Earthly places that scientists believe are similar to places on other planets.

Ellesmere Island's Borup Fiord Pass offers a unique analog on Earth for what may be a future field site on Europa. Our website hosted reports from the Ellesmere science team about chemical similarities between the two places, possible hydrological similarities, and study of microbial life beneath the Borup Fiord glaciers that could provide clues about the kinds of habitats for life that might exist beneath Europa's crust.

At the Arctic island of Spitsbergen, a great Mars analog, the Society and NASA's Astrobiology Program tested a modified Mark III spacesuit (for the Moon and Mars). Our human explorer also worked with a rover to test how best to coordinate human and robotic activities.

The Mysterious *Pioneer* Anomaly

Society members rallied to help solve the *Pioneer* Anomaly (the unexplained rate of slowing of *Pioneer 10* and *11*, which launched to Jupiter and Saturn more than 30 years ago.) Your support has enabled scientists and engineers to recover much of the spacecrafts' navigational histories. These data may help solve the mystery.



International Lunar Decade

The European Space Agency's *SMART-1* ended a successful lunar mission and left a legacy for future missions. The Society, recognizing the Moon as a stepping-stone into the solar system, has called for an International Lunar Decade to start in 2007.

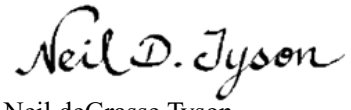
With You, We Are a Team of Space Explorers

We are a formidable public force for space exploration, yet, as can be seen on our balance sheet, membership is decreasing even as renewals and donations remain high. In response, the Society is expanding its outreach and targeting new audiences—especially young people. You can help: introduce someone to the Society, perhaps your child or grandchild, and shape the next space age.

Your generous support has enabled the Society to take on myriad projects, including our next attempt to fly a solar sail mission and our Apophis competition to design a mission to "tag" a near-Earth asteroid.

With you, we will continue to lead the way in seeking other life and exploring worlds beyond our own.

Sincerely yours,



Neil deGrasse Tyson
Chair, Board of Directors

Neil is also an astrophysicist and director of the Hayden Planetarium of the American Museum of Natural History in New York City.

Balance Sheet

For the Fiscal Years Ended September 30, 2002, 2003, 2004, 2005, and 2006 in thousands of dollars.

	Total All Funds:				
Assets	**FY2006**	**FY2005**	**FY2004**	**FY2003**	**FY2002**
Current Assets					
Cash and Cash Equivalents and Investments	1,304	1,511	1,572	1,959	2,274
Membership Dues and Misc. Receivables	206	277	209	114	5
Inventories	50	64	53	47	49
Prepaid Expenses	26	49	51	21	20
Total Current Assets	**1,586**	**1,901**	**1,885**	**2,141**	**2,348**
Land, Building, and Equipment	**655**	**683**	**638**	**658**	**698**
Total Assets	**2,241**	**2,584**	**2,523**	**2,799**	**3,046**
Liabilities	FY2006	FY2005	FY2004	FY2003	FY2002
Accounts Payable and Accrued Expenses	195	206	129	101	170
Deferred Dues and Grant Revenue*	1,065	1,147	1,247	1,420	1,864
Total Liabilities	**1,260**	**1,353**	**1,376**	**1,521**	**2,034**
Net Assets (Deficits)	FY2006	FY2005	FY2004	FY2003	FY2002
Unrestricted	633	844	(96)	60	28
Temporarily Unrestricted	346	385	1,241	1,217	983
Permanently Restricted	2	2	2	1	1
Total Net Assets	**981**	**1,231**	**1,147**	**1,278**	**1,012**
Total Liabilities and Net Assets (Fund Balances)	**2,241**	**2,584**	**2,523**	**2,799**	**3,046**
Revenues	FY2006	FY2005	FY2004	FY2003	FY2002
Membership Dues	1,299	1,366	1,538	1,636	1,703
Donations/Grants	1,180	1,610	1,230	1,495	1,285
Bequests	37	72	0	10	631
Other **	396	208	282	258	288
Solar Sail Grant	0	0	0	0	677
Total	**2,912**	**3,256**	**3,050**	**3,399**	**4,584**
Expenses	FY2006	FY2005	FY2004	FY2003	FY2002
Member Development and Fundraising	443	421	380	342	339
Publications: Print and Web	535	554	721	629	749
Education and Information	182	117	121	102	129
Programs ***	432	418	455	551	430
Member Services	338	343	331	312	394
Administration	317	312	338	408	394
Projects	798	579	703	561	1,097
Special Solar Sail Expenses	117	428	132	228	326
Total	**3,162**	**3,172**	**3,181**	**3,133**	**3,858**

* Income received but not yet recognized ** Admissions, interest, net sales, royalties, etc. *** Events, lectures, tours, and expeditions

We Make It Happen!

by Bruce Betts

New Horizons at Jupiter and a Digital Time Capsule

On February 27 and 28, 2007, the *New Horizons* spacecraft successfully made a close-approach flyby of Jupiter, doing great science and adding nearly 10,000 miles per hour to its speed on the flight to Pluto. This was a huge milestone for *New Horizons* and its talented team of scientists and engineers. It was also a success for Planetary Society members who truly helped make this mission happen.

Our Success!

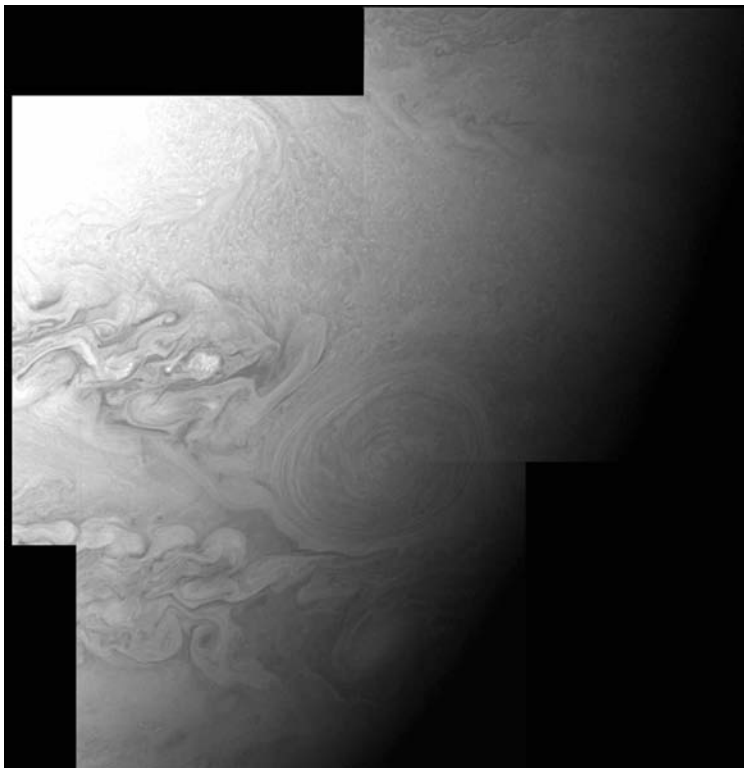
Few missions have been as popular with the public or faced such a political challenge coming to flight. More than once, *New Horizons* was near cancellation and brought back through efforts led by the grassroots efforts of Planetary Society members. When I attended the Jupiter encounter at the Applied Physics Laboratory in Maryland, *New Horizons*' Principal Investigator Alan Stern referred to The Planetary Society as "the cavalry who was always there when there was trouble."

New Horizons has already returned spectacular images of Jupiter's cloud systems, Io's volcanic plumes, and the Galilean satellites, and more Jovian system science will be coming back over the next few months. Keep an eye out for more coverage in *The Planetary Report*, on *planetary.org*, and from Planetary Radio.

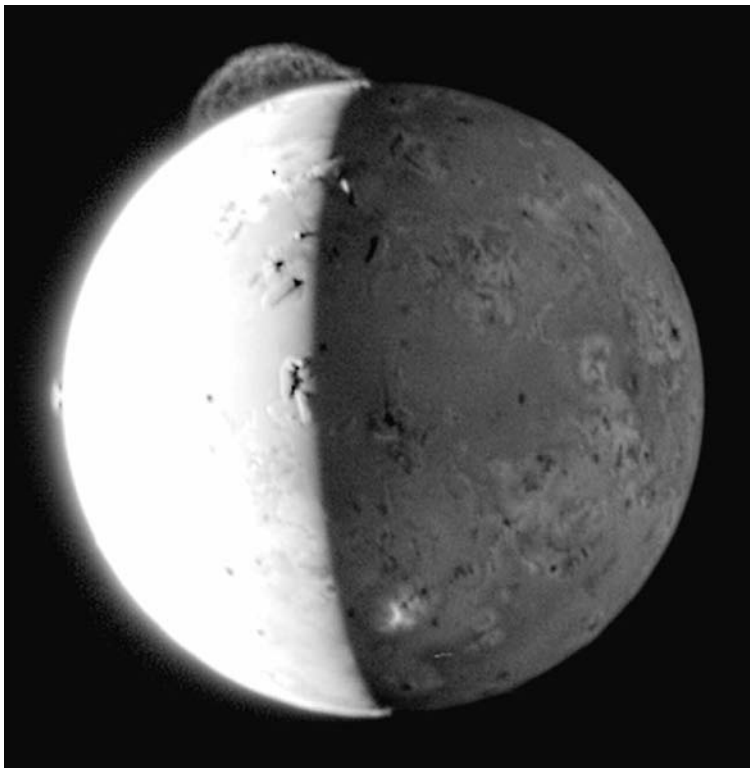
New Horizons' examination of the Jovian system has been unique, featuring the best opportunity (due to geometry and sensitivity of instruments) to study Jupiter's rings, the first flight down the enormous magnetotail of Jupiter, a fortunate occurrence of volcanic activity seen on Io, and compositional spectral data from regions of the icy satellites that have never been studied spectroscopically. All of this is in addition to a wealth of data about the always-changing Jovian atmosphere.

A Digital Time Capsule

What will change on Earth between now and 2015, when *New Horizons* reaches Pluto? That is the question



This is a mosaic of three New Horizons *images of Oval BA, also known as Jupiter's Little Red Spot, taken on February 26, 2007 from a range of 3.5 million kilometers (2.1 million miles). The area measures 33,000 kilometers (20,000 miles) from top to bottom, about 2.5 times the diameter of Earth.*



New Horizons *captured this image of Jupiter's moon Io on February 28, 2007, just five hours after its closest approach to Jupiter. The dramatic plume at the top of the globe is Tvashtar, shooting 290 kilometers (180 miles) into space. The smaller plume to the left is Prometheus, rising 60 kilometers (40 miles).*

Images: NASA/JHUAPL/SwRI

What's **Up?**

In the Sky—April and May

Venus dominates the early evening, looking like the brightest star in the sky in the west. On May 19, it will appear very close to the crescent Moon. Mercury is to the lower right of Venus in late May just after sunset. Saturn is high overhead in the early evening, looking like a bright, yellowish star. Saturn appears to be very close to the Moon on April 24 and to the upper left of Venus by the end of May. Looking like a very bright star, Jupiter rises in the east around midnight in early April and soon after sunset by the end of May. Mars is up in the predawn eastern sky, looking reddish.

Random Space Fact

Jupiter now has a Little Red Spot to complement its Great Red Spot. The Little Red Spot formed over the last several years. Three white oval storms merged into one storm, and then, in 2006, the storm reddened. "Little" is misleading: this reddish storm is nearly as large as Earth.

Trivia Contest

Our November/December contest winner is Carol Kucera of Santa Fe, New Mexico. Congratulations!

The Question was: What feline name has been applied to the large "cracks" that run along Enceladus' south pole and that appear to be sources of water-ice and gas coming out of Enceladus?

The Answer: Tiger stripes.

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

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 June 1, 2007. 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.*

we posed to the world when we invited digital photos and captions for our *New Horizons* Digital Time Capsule contest. We wanted a set of images that captured aspects of Earth in 2006 that we could reflect upon in 2015. In the end, we selected 50 images from entrants in 17 countries for inclusion in the digital time capsule, which will be stored at The Planetary Society with a backup at the Applied Physics Laboratory.

From the chosen 50, we randomly selected our grand prize winner, Bill Sterns from Wylie, Texas. For his prize, Bill attended the *New Horizons* Jupiter encounter and science team meeting. At the encounter, Bill told me he was struck by the complexity and effort that goes into a mission like this—a very successful mission thus far that, in no small part, we made happen.

Bruce Betts is director of projects at The Planetary Society.

Members can view all 50 images until May 31 at *planetary.org/explore/topics/time_capsule/preview.html*

Questions and Answers

While reading Jim Bell's article "Photographing Mars" (see the November/December 2006 issue of* The Planetary Report*), something caught my eye. Certain portions of the rim of Beagle crater are smooth, while adjacent areas are still rough. It appears that the ground fragmented upon the initial shock wave of the impact, but why are only some areas of the bedrock smooth while others are not? My best guess is sand shear, but I would expect to find a more uniform distribution of smoothness throughout the crater rim.

Do any of you have an answer to this mystery?

—Philip Crume
Bay Village, Ohio

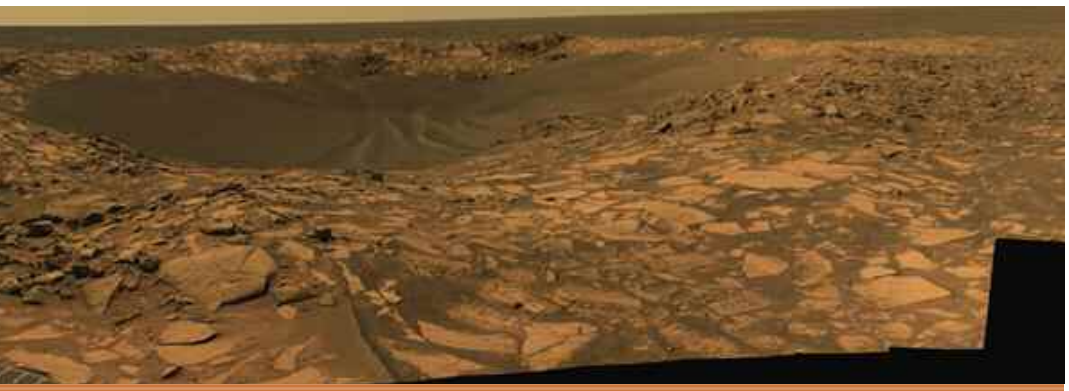
The geology of Beagle crater is interesting (see image below). We know from the rover *Opportunity*'s observations that the material that formed the dunes and ripples in the middle of the crater is basaltic sand—particles of ground-down volcanic rock measuring hundreds of microns to a millimeter in diameter—rather than dust. Sand has been moving across the dark plains of Meridiani Planum for eons, and some of it appears to have become trapped in this small crater.

Your observation that parts of the crater's ejecta blanket (material thrown out of the crater by the impact event) are smooth and other parts are rough is a good one. As far as I know, there's no single obvious explanation for this. One possibility is that there has been preferential erosion (the "sand shear" you mentioned) of the ejecta from consistent winds coming from the same direction for a very long time. It's hard to know if this explains the observations, however, because we believe Beagle is a fairly young impact crater—its ejecta hasn't been completely worn away, as has that of other craters in Meridiani such as Eagle, Endurance, and Victoria, the three craters studied most extensively by *Opportunity*.

Another possibility is that we see patchy blockiness in the ejecta because the subsurface material that was excavated by the impact was itself patchy. The rover's traverse from Eagle to Victoria tells us that the outcrop in Meridiani is patchy, so maybe what we're seeing is just natural, "clumpy" ejecta deposits like we see in some crater rays on the Moon.

There may be other explanations as well. Certainly the ground was shocked and fractured when the small asteroid or comet that created Beagle crater crashed into the Martian surface. Putting the "forensic" pieces of evidence together to figure out exactly what happened after that is difficult to do, however, and may require a lot more analysis of the rover's images and other data.

—JIM BELL,
Cornell University



Opportunity ***approached Beagle crater, an impact crater about 35 meters wide, in August 2006. Though it looks relatively fresh in orbital images, from a closer vantage point, Beagle crater appears moderately eroded. Because impact craters have well-understood shapes when they form, the altered appearance of eroded craters gives scientists clues to the processes that modified them. By observing how filled an impact crater has become and how worn its edges are, scientists can estimate how long its surface has been exposed to erosion. The many-sided outline of a crater such as Beagle and the blocky appearance of its ejecta may also tell scientists about the strength of the underlying bedrock.*** *Image: NASA/JPL-Caltech/Cornell/UNM*

When I hear about asteroid defense strategies, scientists always say, "We don't want to break up the object, because then there would be multiple impacts." Yet, this seems like the best plan if the object couldn't be diverted. The smaller pieces would burn up in the atmosphere, and even the larger pieces that made it to the ground would expend less energy on impact, thus pushing less debris into the stratosphere. Why are the experts against breaking up a large object into smaller objects?

—Ed Swaneck,
Columbus, Ohio

If we could guarantee that a threatening object could be broken up into pieces small enough to burn up completely on entry through the atmosphere, then such a strategy might indeed work—with some caveats.

We have to consider that even if disrupted into small pieces, the total impact energy of the original threatening object would still be delivered to Earth. So, let's say we turned an asteroid a kilometer (0.6 mile) wide into a million 10-meter (33-foot) fragments and all those fragments still hit the planet. Even though each individual impactor might make only a window-rattling boom in the lower atmosphere (that's one such boom over every patch of about 250 square kilometers, or about 90 square miles, on one side of the entire planet—a

pretty impressive outcome in itself), all of the original impactor's material and impact energy would still be deposited in the atmosphere. The problem here is that for typical rocky asteroid mineral compositions, there is enough ozone-destroying chlorine and bromine in a kilometer-wide asteroid to completely wipe out our protective ozone layer at least once over. We might have escaped the immediate blast effects of a single large object reaching the surface, but we'd still be in considerable trouble.

A solution to this problem would be to disrupt the asteroid long enough before the impact that its small fragments are dispersed enough so that only a small fraction end up hitting the planet. This would require a bit more lead time but still less than would be needed for the preferred methods of gradual, gentle thrusting on the object many years before an impending impact. The "blow it to smithereens" tactic (via kinetic kill or nuclear detonation, for example) might be our option of last resort in case another deflection mission fails, or if we have very short notice of an impending significant impact (very rare, but possible).

Our biggest concern with techniques that would break a threatening object apart is that we still know so little about the internal properties of asteroids. We cannot predict how they will respond to attempts to tear them asunder (let alone guarantee that the outcome will indeed result in many small pieces). Such methods are inherently uncontrollable. Additional concerns might arise once the actual method of delivering the breakup energy to the asteroid is chosen. For example, could we even launch a massive enough kinetic-kill spacecraft necessary to do the job? Some people might not look favorably upon the idea of using nuclear weapons in space.

If we're going to have technologies and techniques for moving around the inner solar system and for exploring and utilizing the near-Earth asteroids for their scientific and mineral riches anyway (and we will, before we're ever likely to have to deal with a large impending impact), then we might as well use those capabilities to be sure of a controlled and safe deflection outcome.

—DANIEL D. DURDA,
Southwest Research Institute

Factinos

Scientists using the Spitzer Space Telescope have found that the atmospheres of gas giant planets orbiting distant stars appear to contain no water. They had long assumed that such planets contain substantial amounts of water, which would be present as vapor in their atmosphere. The spectra obtained by Spitzer, however, show no water at all.

Three teams of scientists focused Spitzer on 2 of the 14 extrasolar planets known to pass directly in front of their star when observed from Earth. To detect the light signal from the planet alone, they first measured the combined spectrum of the star and planet when the planet was close by the star. They then took a second measurement of the star alone, when the planet disappeared behind it. The difference between the two spectra consists of the planet's contribution of the combined spectrum—that is, only of light from the planet.

One team, led by Carl Grillmair of Goddard Space Center, focused on planet HD 189733b, and two teams, led by Jeremy Richardson and Mark Swain of the Jet Propulsion Laboratory, observed HD 209458b. Both planets are "hot Jupiters," gas giants that orbit very close to their parent star. All three teams arrived at the same conclusion: the light spectra from the two planets show no evidence of water vapor in the atmosphere.

The fact that water and other common atmospheric components were not detected in the planets' spectra does not mean that they are not there, and in fact, scientists think the water may be hidden. The spectrum of planet HD 209458b contained hints of silicate molecules. On Earth, such molecules usually are present as sand or in rocks, but on a hot Jupiter, they would exist as tiny dust grains floating in the atmosphere. If clouds of silicate dust envelope the surface of these distant giants, then they could certainly block out the signals from water vapor and other atmospheric components.

—from *planetary.org*

For the first time, astronomers have witnessed the speeding up of an asteroid's rotation due to a theoretical effect that has been predicted but never before seen—the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect.

An international team of scientists directly observed the YORP effect on a small near-Earth asteroid known as (54509) 2000 PH5. The team found that 2000 PH5's rotation period is decreasing by 1 millisecond every year as a consequence of the heating of the asteroid's surface by the Sun. Although this is an almost immeasurably weak force, its effect over millions of years could be significant. Astronomers believe the YORP effect may be responsible for spinning some asteroids so fast that they break apart, perhaps leading to the formation of double asteroids.

Over four years, researchers Stephen Lowry, Alan Fitzsimmons, and colleagues took images of the asteroid from a variety of telescope sites; they measured the slight brightness variations as the asteroid rotated.

Over the same period, a radar team led by Patrick Taylor and Jean-Luc Margot of Cornell University employed the unique capabilities of the Arecibo Observatory in Puerto Rico and the Goldstone radar facility in California to observe the asteroid by bouncing a radar pulse off it and analyzing the echo.

The asteroid's spin rate was seen to increase steadily with time, at a rate that can be explained by the YORP theory. To predict what will happen to the asteroid in the future, Lowry and his colleagues performed detailed computer simulations using the measured strength of the YORP effect and the detailed shape model. They found that the orbit of the asteroid about the Sun could remain stable for up to 35 million years, allowing the rotation period to be reduced to just 20 seconds, faster than any asteroid whose rotation has been measured until now.

—from the European Southern Observatory

Society News

50th Anniversary of the Space Age

What's your vision for space? We want to know.

Over a cup of coffee, our associate director, Charlene Anderson, turned to me and asked, "What's your vision for space? How do you want to introduce your child to the future?"

That's a tough question—and one I greet with optimism and a sense of urgency. In just months, on October 4, we will celebrate 50 years since the launch of *Sputnik 1*—the beginning of the Space Age.

Please join me in answering Charlene. What do you envision for the next half-century in space? To what future do you want to introduce a new generation? Tell us in 50 to 250 words, and as we count down to October 4, we'll post selected comments on our website to share with the world.

You can help us shape The Planetary Society's future programs and, through our organization, shape humanity's future in space.

You can e-mail me your statement at *andrea.carroll@planetary.org*, fax it to me at (626) 793-5528, or send it via post to my attention at The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106-2301.

—Andrea Carroll,
Director of Development

Gift Planning— A Bridge to the Future

Many of you have already remembered The Planetary Society in your estate planning. Thank you from us, and thank you from all those future members who will benefit from your legacy.

For those of you planning your estate, please know that your gift is a bridge to the future. Your planned gift can bolster projects, operations, and grant programs. Your gift can provide crucial funding for unanticipated initiatives. A bequest in your will—of cash, securities, life insurance, real estate, or other property—is a meaningful gift to the Society, and it may also enable you to retain current assets and save on estate taxes later.

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

Again, thank you to all of you who have already so generously included us in your plans.

—AC

Annual Audit Completed

The firm of Hensiek & Caron has completed its yearly audit of The Planetary Society. The firm determined that the Society's 2006 financial statement was in conformity with generally accepted accounting principles.

Copies of the financial statement are available upon request.

—Lu Coffing,
Financial Manager

Members' Dialogue

Why Do We Explore Space?

In the previous issue, we asked you to send in your answer to that question. Here are some of the responses we have received so far.

The answer is simple: exploration defines our species. Other species may explore new territory to find a mate or a new source of food or to start a new colony. Humans are the only species, that I'm aware of, that explore for the acquisition of knowledge. We are dealers in information, seeking answers to the mysterious and wondrous world around us—describing, naming, cataloging, and categorizing each new discovery.

Exploration is our true essence. We crave knowledge. But with that knowledge comes a tremendous responsibility to use it in an intelligent manner. To fulfill our destiny, we must boldly go forward and continue to explore the world around us. The potential is tremendous. Will we raise humanity higher and realize that potential?

—MARCUS PRAZNIAK,
El Cerrito, California

We explore space because that's the right thing to do. As humans, we long for knowledge. Acquiring knowledge is necessary for survival. I rely on The Planetary Society to learn about what is out there. Learning about space does equip us to be better stewards of Earth's resources. It should also help us learn to live in community right here on Earth.

Institutions like The Planetary Society should consider the question: What can we learn from our projects that can be used to improve life conditions on Earth?

—LUCIANO FLEISCHFRESSER,
Enid, Oklahoma

Erratum

Our January/February 2007 issue has an error on page 8 ("Lunar Mysteries Beckon"). In the box "What Is Helium-3?", the description of tritium should read "tritium, also known as hydrogen-3, which has one proton and two neutrons" instead of "three protons and no neutrons."

—Editor

Please e-mail your letters to *tps.des@planetary.org*

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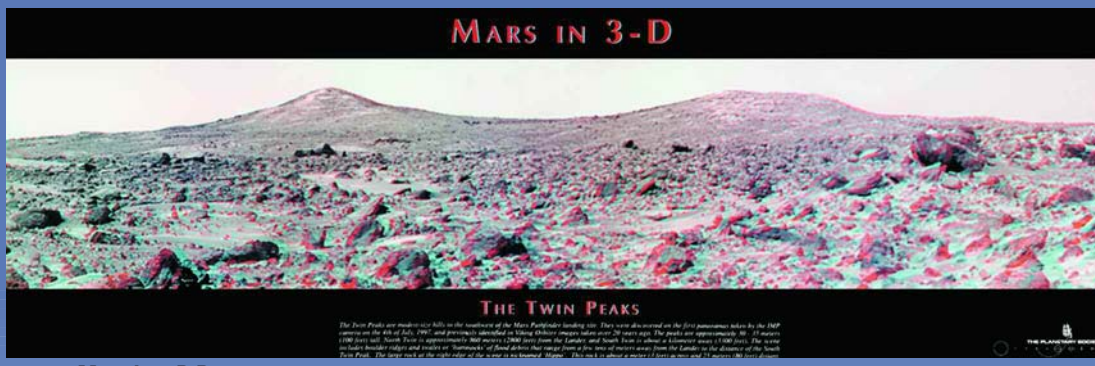

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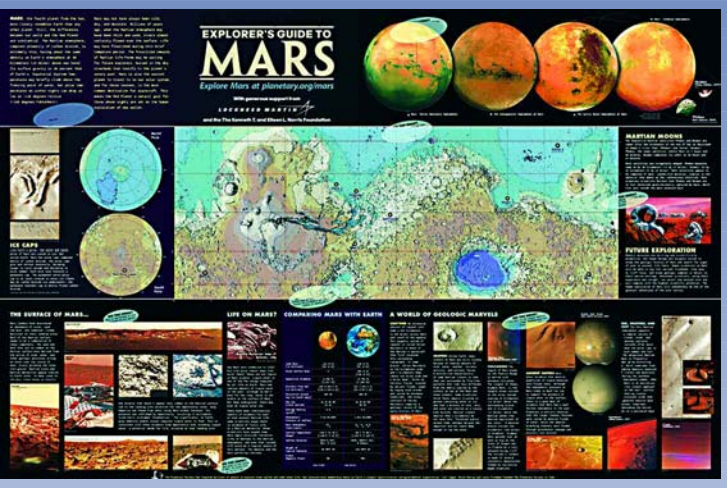

An Explorer's Guide to Mars Poster
Images from *Mars Global Surveyor*, speculative paintings of the Red Planet's past and future, informative captions and charts, and images of Mars' surface from the *Pathfinder* and *Viking* spacecraft enhance a detailed U.S. Geological Survey map. 24" x 37"
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On a misty morning close to the southern ridge of Mars' Holden crater, thin, finger-like clouds appear to fan out from the rising Sun. Holden crater sits about 2,100 kilometers (1,300 miles) southwest of Meridiani Planum, where the Mars Exploration Rover *Opportunity* has found ample evidence that liquid water once flowed on the Red Planet's surface. Holden's floor, which is 154 kilometers (96 miles) wide, shows enough signs (layered sediments, channels, and big piles of debris at canyon mouths) that ancient water flowed there to qualify the area as a potential landing site for NASA's next Mars rover, the *Mars Science Laboratory*, scheduled to launch in 2009. Kees Veenenbos used data from the Mars Orbiter Laser Altimeter on *Mars Global Surveyor* to produce this landscape.

Kees Veenenbos is a graphic artist who lives and works in Apeldoorn, The Netherlands. His digital visualizations of ancient, present-day, and future Mars have been published in *National Geographic, Sky & Telescope, Science, Ciel & Espace, Astronomy,* and *GEO*. In 2005, he was nominated for an Emmy Award for artwork that appeared in the Public Broadcasting Station's *NOVA* episode titled "MARS Dead or Alive."

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