The PLANETARY REPORT

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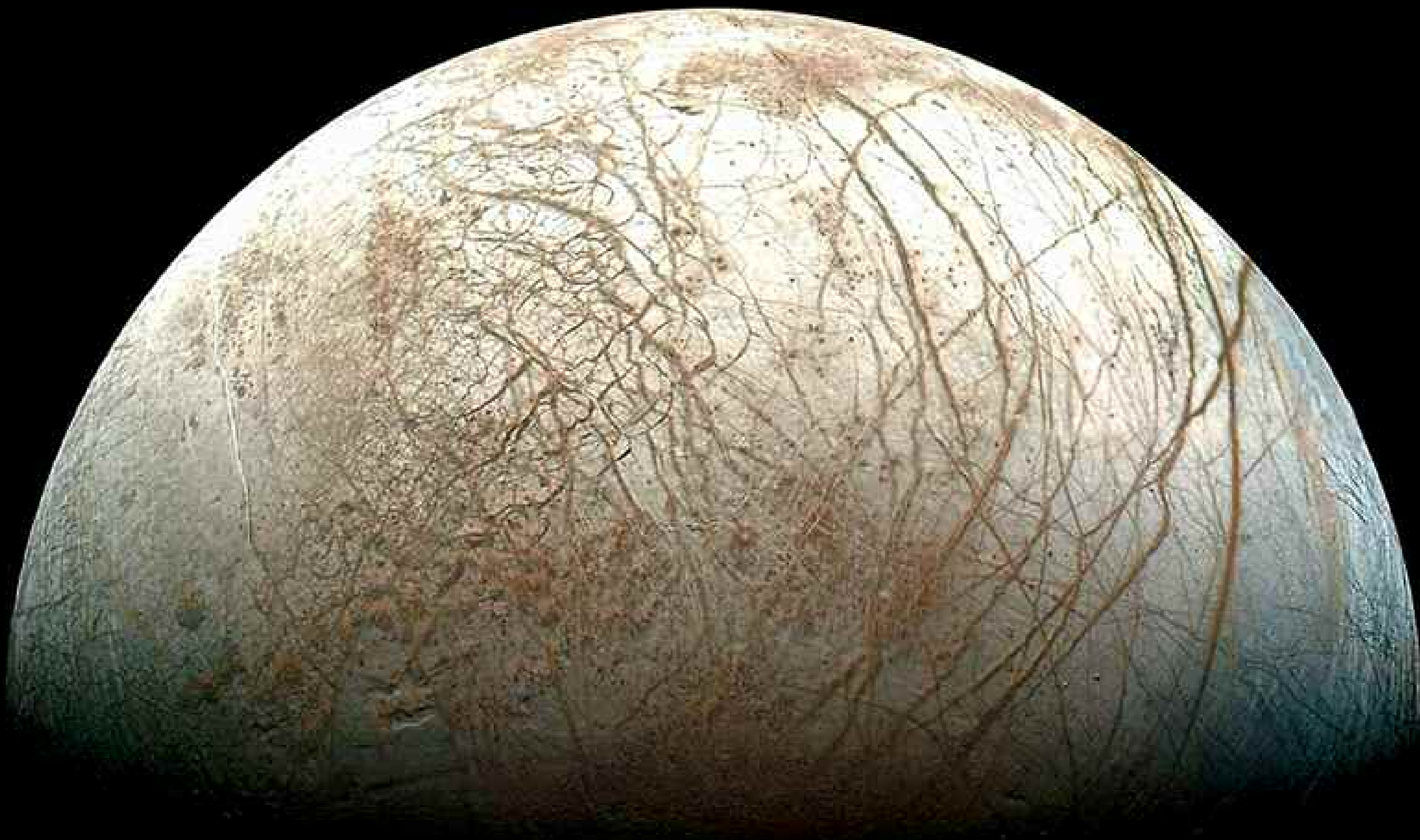

Other Oceans? Other Life?

FROM THE EDITOR

You know me—if you've been around The Planetary Society for a while—and know that Europa is my world. Since 1979, when I first saw that icy little moon through *Voyager*'s eyes, Europa has been the world above all others that I want to know. Even with *Voyager*'s distant glimpses, people began to speculate that an ocean lay hidden beneath the uncannily smooth ice. And you know how it goes in space science: where there's liquid water, people start talking about life.

The *Voyager*s teased us about Europa and moved on. In the 1990s, *Galileo* tantalized us, dangling the near certainty of a Europan ocean just out of reach of the spacecraft's inquiring instruments. In this decade, the U.S. National Research Council set a mission to Europa as its first priority for scientific space exploration.

What is the status of the next mission to Europa? Stuck in planning. Waiting for funding. The Planetary Society still fighting for a "new start."

In this issue, we'll bring you up to date on research on Europa—as well as the possibilities of oceans on other moons—and demonstrate why we need to return. We'll also visit Mars, another world that sparks talk of life. Mission after mission has brought us closer and closer to understanding the Red Planet, and ever more capable spacecraft have been searching for their predecessors on Mars.

Meanwhile, the Society keeps working toward Europa . . . and other tantalizing worlds. And I appreciate—personally—all your help.
—*Charlene M. Anderson*

ON THE COVER:

Europa's surface—young, smooth, and icy—is one of the brightest in the solar system. The dark, scribble-like lines and cracks that wrap around its exterior are evidence of an ocean below this Jovian moon's frozen shell. This view of Europa, a mosaic of *Galileo* images, was processed to show its natural colors.

Oceans might also exist beneath the surfaces of other icy moons in our solar system, such as Ganymede, Titan, Triton, and Enceladus. We'll know for sure only by sending spacecraft back for a closer look.

Image: NASA/JPL, reprocessed by Ted Stryk

BACKGROUND:

In this view of a small region of the thin, disrupted ice crust in Europa's Conamara region, the white and blue areas have been blanketed with a fine dust of ice particles—ejecta from the formation of the impact crater Pwyll, which lies about 1,000 kilometers (about 600 miles) to the south (not visible here). The reddish brown zone is unblanketed surface that has been painted by mineral contaminants carried and spread by water vapor released from below the crust when it was disrupted. The colors in this mosaic of *Galileo* images have been enhanced for visibility (but lightened for background printing). This picture covers an area about 70 by 30 kilometers (44 by 20 miles); north is at the top. Image: NASA/JPL

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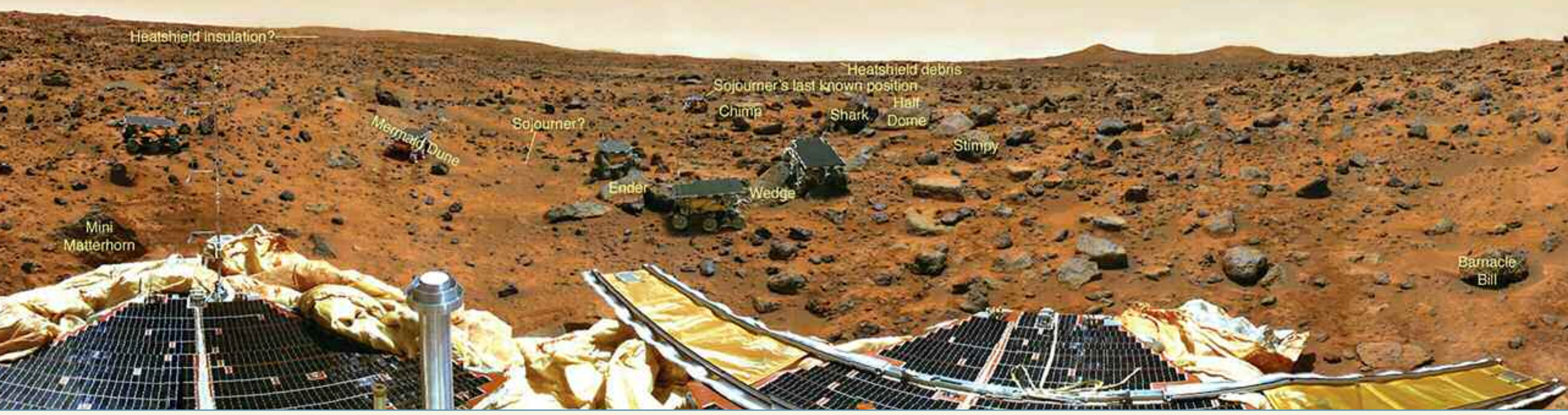
SEARCHING FOR OURSELVES ON MARS

Finding the *Viking* and *Mars Pathfinder* Landing Sites from Orbit



This version of the* Mars Pathfinder *"Gallery Panorama," taken by the camera on the lander, depicts many of the rover* Sojourner*'s "end of sol" positions (where it "bedded down" for the Martian nights). The rover's last known position is indicated, as well as the rover-size feature that may be where* Sojourner *drove after losing contact with the lander

Image: NASA/JPL/Ames Research Center

BY TIMOTHY J. PARKER

Almost as soon as the *Mars Reconnaissance Orbiter* science operations began last fall, the HiRISE (High Resolution Imaging Science Experiment) team began looking for the landing sites of both *Viking* landers and *Mars Pathfinder*, as well as the Mars Exploration Rovers, *Spirit* and *Opportunity*, which landed on Mars in early 2004. HiRISE successfully captured all five sites with sufficient detail to conclusively place the landers and much of the associated entry, descent, and landing hardware. I had the good fortune to be part of this effort.

More than 32 years have passed since the *Viking 1* and *2* landers touched down on Mars and began surface operations. At the time of these landings, I was a deck carpenter working for a yacht manufacturer. When *Viking 1* began sending data back, I decided to pursue a degree in geology in the hope that I might be able to participate in future Mars exploration.

Ten years ago, and more than 20 years after the *Viking* landings, *Mars Pathfinder* became the third NASA spacecraft to touch down safely on Mars, at a site southeast of the *Viking 1* landing site. I had been involved with the landing site selection process for the mission. We used images from the *Viking 1* and *2* orbiters to create maps to help the project team, the planetary science community, and the NASA review panels select the safest and most interesting site for the *Pathfinder* mission.

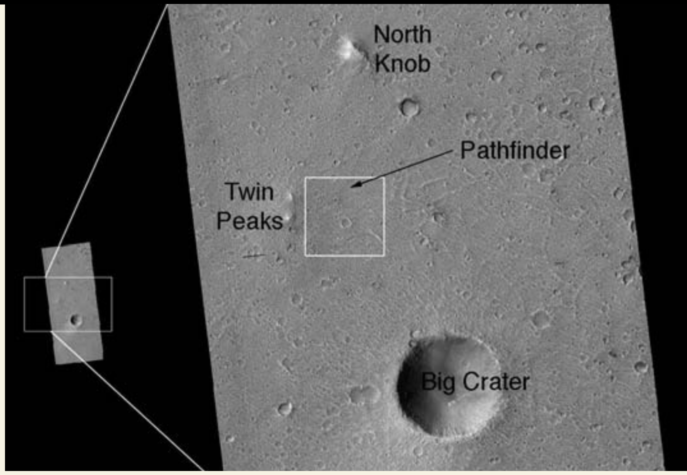
The best images available at the time of the *Viking 1* and *2* and *Pathfinder* landings were too low in resolution for us to see the landers on the surface of Mars once they touched down. Fortunately, all three landing sites contained horizon features that could be identified from orbit, so we could approximate the landers' locations on the surface by comparing these features with views from orbit. Actual detection of the landers themselves had to await the arrival of cameras in Mars orbit with much higher resolution.

Although determining accurate locations for the vehicles was not critical for surface operations during the *Viking* and *Pathfinder* missions, locating such vehicles is nonetheless highly desirable for defining the geologic setting of the landing sites and for putting the surface science results into a broader perspective. High-resolution orbiter images—first acquired by the Mars Orbiter Camera (MOC) on *Mars Global Surveyor* beginning in 1997 and followed by HiRISE—allow scientists to "bridge the gap" between the regional coverage provided by the *Viking* orbiters and the ground views from the landers.

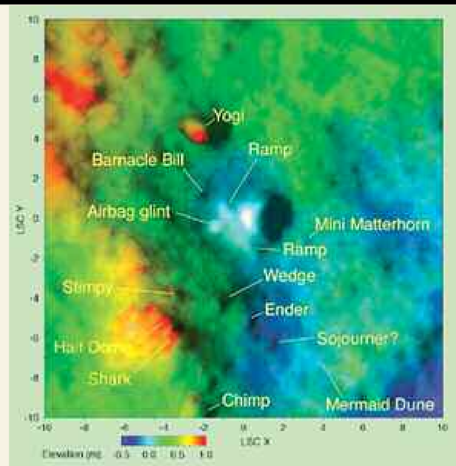
KNOWING WHERE TO LOOK

The key to finding our landers and other hardware on Mars is knowing exactly where to look. In the case of finding the *Viking 1* lander, we targeted MOC and HiRISE using revised coordinates that were set after the *Pathfinder* landing in 1997. We discoverd that *Pathfinder* had landed several kilometers east of the expected site, based on where we thought *Viking 1* had landed in the late 1970s. This caused a number of Mars scientists and cartographers to suggest that the published location of *Viking 1* might be wrong, so we went to work examining the data to see if we would come to a different conclusion.

The *Viking 2* orbiter took an image of the *Viking 1* landing site with a resolution of about seven meters per pixel (that is, each point in the image covers about seven meters). The image is rather "noisy" but shows enough detail to allow us to find a number of small craters that were identified as ridges during the *Viking* mission. By triangulating to these ridges, I was able to come up with a location that fit the data better than the one derived during the *Viking* mission—a location about six kilometers (about three and a half miles) northeast of the earlier location. It was with this newly revised location that we were able to target MOC and HiRISE to search for, and



No sooner had the Mars Reconnaissance Orbiter *achieved orbit than the science team began using the amazingly sharp "vision" of the High Resolution Imaging Science Experiment (HiRISE) on board to look for the landing sites of both* Viking*s as well as those of* Mars Pathfinder *and of the Mars Exploration Rovers* Spirit *and* Opportunity*. HiRISE took this image of the region surrounding the* Mars Pathfinder *landing site. The white box in the larger view outlines the image at right.* Image: NASA/JPL/University of Arizona/USGS



This HiRISE close-up of the Pathfinder *lander shows many of the same rocks and other features from the Gallery Panorama in their proper positions relative to the lander. The dark spot labeled "*Sojourner*?" was not present when the Gallery Panorama was taken. This suggests that* Sojourner *may have moved into that position after it was imaged by the lander's Imager for* Mars Pathfinder*.*
Image: NASA/JPL/University of Arizona/USGS

ultimately find, both *Viking 1* and *Pathfinder*.

Using *Viking* Orbiter Images

Although the *Viking* orbiter images are too low in resolution to detect the landers or associated hardware, as with *Viking 1*, they helped us better predict the lander locations so we could correctly target MOC and HiRISE.

The area of Mars where *Mars Pathfinder* landed has the most complete coverage from *Viking* orbiter images. The Ares Vallis site where *Pathfinder* landed was the primary landing site for the *Viking 1* lander, but it was later deemed to be too rocky and a possible danger to the lander. *Viking* images of Ares Vallis have a resolution of about 40 meters per pixel, and some stereo images of the site exist.

Of the three landing sites, *Viking 2* has the lowest resolution coverage from the *Viking* orbiters—only about 100 meters per pixel at the actual landing site. Like the *Viking 1* lander, *Viking 2*'s initially favored site—west of the actual site—was covered at a resolution of about 40 meters per pixel, but the landing site was abandoned because of its rough appearance.

Contributions of *Mars Global Surveyor*

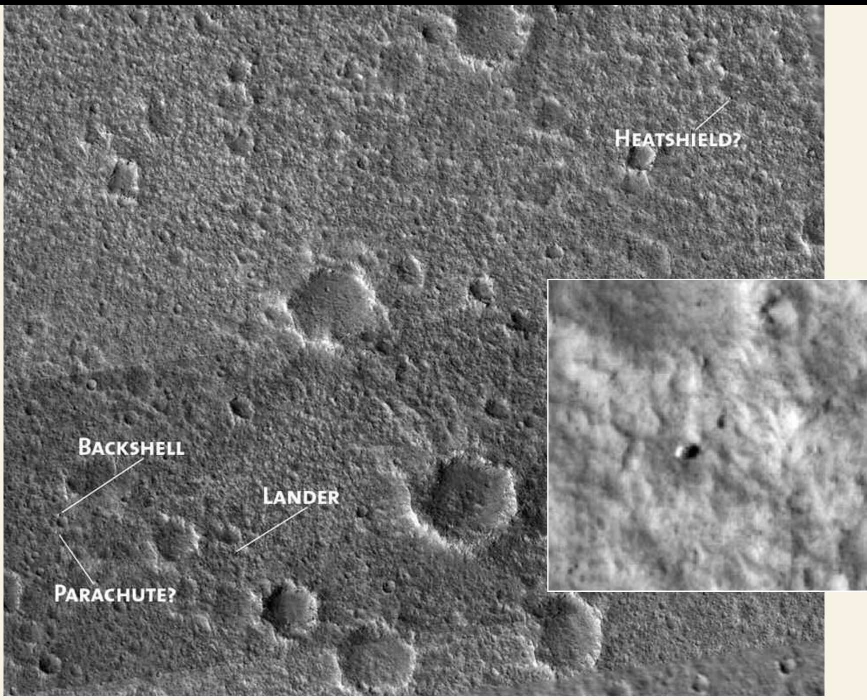
Mars Global Surveyor arrived at Mars in 1997 and began mapping the planet with the keen "eye" of the Mars Orbiter Camera. Throughout nearly 10 years of coverage, MOC imaged all three landing sites at resolutions from about 1.5 to about 3 meters per pixel. Later in the mission, MOC was able to image the sites at "super" resolution by taking images while the spacecraft rolled. Today, after having conclusively identified the landers in HiRISE images, I find it interesting to revisit the MOC images to see just what they reveal or don't reveal at the three landing sites.

The *Viking 1* Lander—Even using MOC's super resolution mode, *Viking 1* is indistinguishable from the surrounding surface, suggesting that sun glints and shadows over the lander mimic the brightness of the surroundings. Objects that we now identify in HiRISE images as the backshell and possibly the heatshield can be seen in the high-resolution MOC image, but they resemble nearby rocks of similar size.

The *Viking 2* Lander—Prior to recent HiRISE data, *Viking 2*'s location was the least precisely known of the three. Terrain features around the *Viking 2* lander site are very subtle. Initial predictions of the lander's location were based on measurements to features such as Goldstone, a "pedestal" crater 3–4 kilometers (2–2.5 miles) wide, located about 12 kilometers (7 miles) northeast of the lander. Although the lander could "see" the dome-shaped profile on the horizon, we couldn't be certain that the lander was seeing Goldstone from its peak all the way to its base. That means that although the direction to Goldstone might be accurate, the distance could be mismeasured by hundreds of meters along the line of sight.

Viking 2 panoramas show other, even more subtle features. Phil Stooke, of the University of Western Ontario, employed a clever technique to enhance the visibility of these features; he simply stretched the panoramas vertically. This technique exaggerates rocks and textures in the near field so they look like posts, and it makes gentle hills and swales along the horizon more recognizable. A few of these geographical features can be used to add to the triangulation provided by Goldstone.

Using a high-resolution MOC image, MOC Principal Investigator Mike Malin, Phil Stooke, and I made predictions of where the lander should be. Mike had even identified an anomalous feature in the image as the lander, but Phil and I could not corroborate the location. When HiRISE took a close look at this area, the mysterious feature was revealed as the *Viking* backshell. The lander turned out to be south of all three predicted locations.



Images from the* Viking *landers and orbiters enabled scientists to predict where the parts of those spacecraft lay on the surface of Mars. The orbiter camera team used this information to target those areas for closer observation by the Mars Orbiter Camera on* Mars Global Surveyor *and by HiRISE. The* Viking 1 *lander (which has a diameter of about three meters), its heat shield, its backshell, and the parachute attached to the backshell are all visible in this HiRISE image. The inset shows an enlarged view of the lander. *Images: NASA/JPL/University of Arizona*

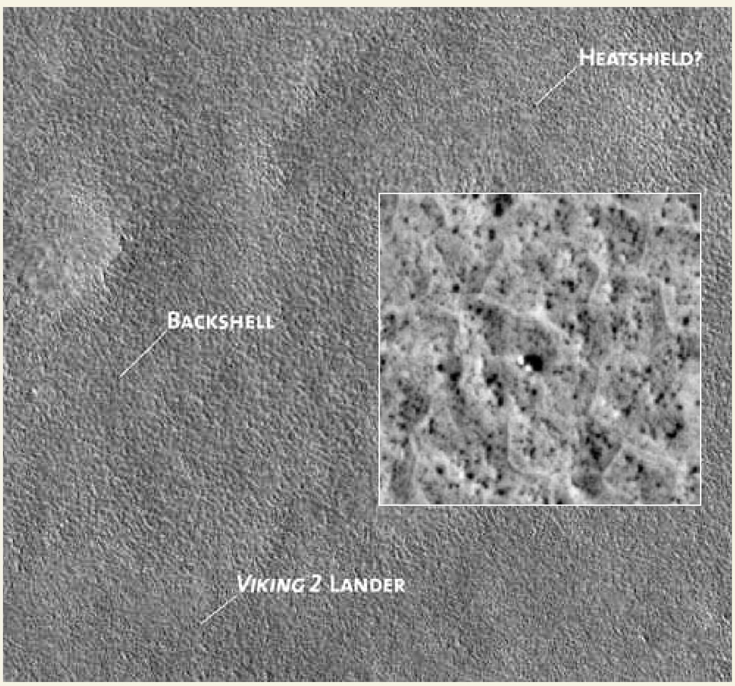
Unlike the situation with the *Viking 1* lander, we were able to identify *Viking 2* in the MOC image, and we think the backshell may be visible as well. In the case of the lander, the low sun and consequent long shadow appear to be the primary reasons that MOC could locate *Viking 2* but not *Viking 1*.

Mars Pathfinder**—**We did well finding *Mars Pathfinder*. The lander's actual location matched my predictions, based on the *Viking* orbiter images, to within a few dozen meters. Using a MOC image, Mike Malin also estimated *Pathfinder*'s location, which turned out to match the actual location in the HiRISE image to within a few meters. The high-resolution MOC image shows the lander as a slightly brighter patch against the surrounding surface, though it isn't recognizable as an anomaly. The backshell and parachute also are visible in MOC images, in which they appear as a pair of unremarkable bright patches. We've even found them in an image acquired less than a year after the landing. In this early image, the parachute appears brighter than in subsequent images, which might mean that dust has accumulated on it over the years.

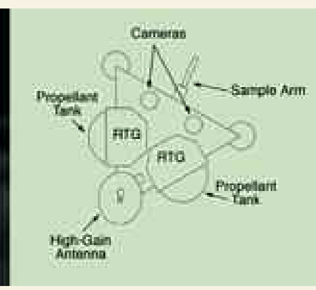
Mars Odyssey Aids in the Hunt

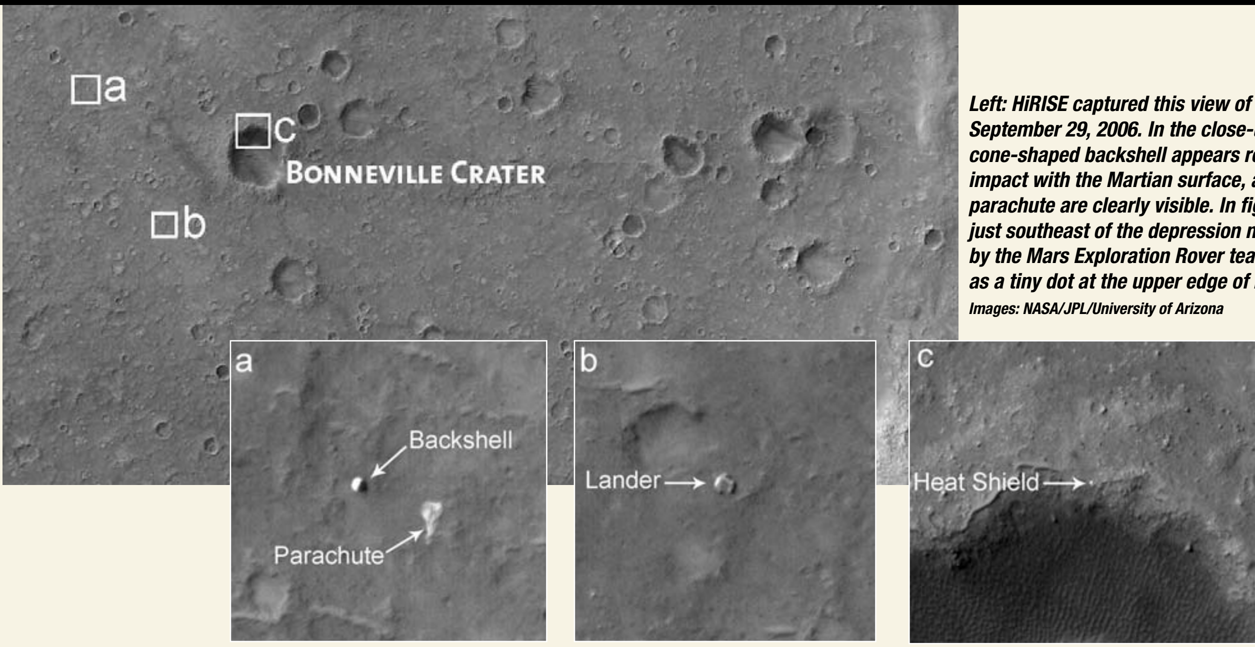
The Thermal Emission Imaging System (THEMIS) on *Mars Odyssey*, which has been examining Mars since early 2002, has two imaging modes. The first is a regional infrared imager that takes data at 100 meters per pixel, either in early predawn or in midafternoon. The second is a visible wavelength mode that acquires images at resolutions as high as 18 meters per pixel. These data have been useful for triangulation purposes, as an intermediate scale between *Viking* orbiter and MOC images, while still covering reasonably large areas around the landers.

THEMIS has imaged all three landing sites at 18 meters per pixel. For the two *Viking* landers, the THEMIS images provide a better regional map for triangulation purposes than do the *Viking* orbiter images. By themselves, however, they are not sufficiently detailed to detect the landers.



The precise location of* Viking 2*'s lander was uncertain for 30 years, until HiRISE came along. By December 2006, mere months after it began operations in Mars orbit, HiRISE had found the Mars Exploration Rovers* Spirit *and* Opportunity *as well as both* Viking *landers. Left: This HiRISE image shows the locations of the* Viking 2 *lander's components. The inset is an enlarged view of the lander. Below: An extreme enlargement of the backshell, taken by MOC, next to a schematic drawing of the lander. *Images: NASA/JPL/University of Arizona/Malin Space Science Systems*





Left: HiRISE captured this view of Spirit's *landing site on September 29, 2006. In the close-up below labeled "a," the cone-shaped backshell appears relatively undamaged by its impact with the Martian surface, and wrinkles and folds in the parachute are clearly visible. In figure b,* Spirit's *lander sits just southeast of the depression nicknamed "Sleepy Hollow" by the Mars Exploration Rover team. The heat shield appears as a tiny dot at the upper edge of Bonneville crater in figure c.*

Images: NASA/JPL/University of Arizona

HiRISE Zooms in on the Targets

In March 2006, the *Mars Reconnaissance Orbiter* arrived at Mars, and soon after, the extremely powerful HiRISE camera joined in the hunt. By October 2006, HiRISE already had found the Mars Exploration Rover *Opportunity*, as well as astounding details such as the rover's wheel tracks. By December 2006, HiRISE had captured images of both *Viking* landers and had found *Spirit* on the surface. In January 2007, we were able to see *Mars Pathfinder* in great detail. Zooming in on the image, one can even make out the ramps, the science deck, and portions of the airbags on the *Pathfinder* lander.

The long-awaited image of *Mars Pathfinder* led to a new hunt. You may recall that the *Pathfinder* lander, which carried the *Sojourner* rover to the surface, fell silent in 1997 because of a hardware failure. As far as we know, *Sojourner* was still functioning when *Pathfinder* failed, but with the lander no longer operating, *Sojourner* had no way to communicate with Earth. How long might *Sojourner* have lasted after loss of the lander? Where might it have been when it ceased functioning? Immediately after the HiRISE image of the *Pathfinder* site was made available, Rob Manning of the Jet Propulsion Laboratory (JPL) and I began poring over the image, looking for anything that might be the rover.

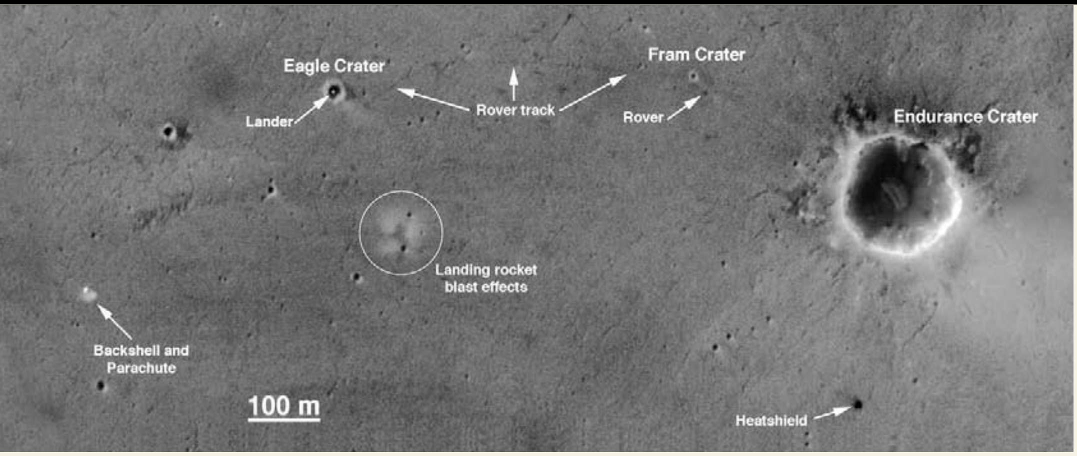
Where Is *Sojourner*?

Sojourner is a relatively small object, much smaller than a single MOC pixel and probably not more than a handful of HiRISE pixels, depending on its orientation in the image. The obvious first place to begin the search was around the lander, because we could compare suspicious "rocks" seen in the HiRISE image and known rocks imaged during the *Pathfinder* mission by the IMP (Imager for *Mars Pathfinder*).

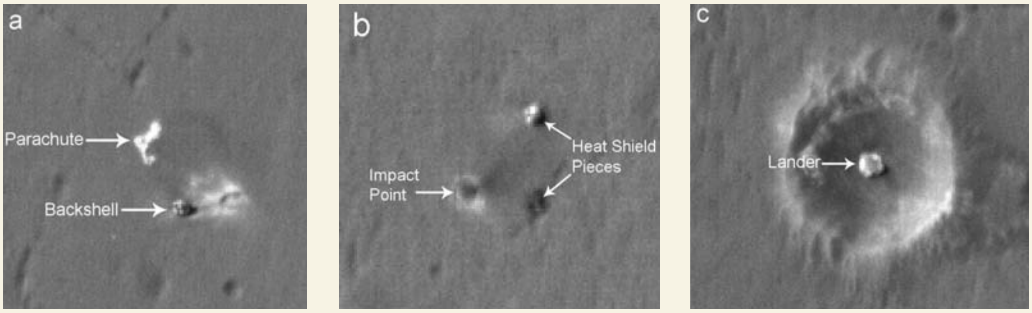
Initially, we didn't find anything obvious, so we wondered whether *Sojourner* might have continued functioning long after the lander failed and traveled tens, hundreds, or even thousands of meters from the lander. *Sojourner* was programmed to try to return to the lander to re-establish contact with *Pathfinder* if it didn't receive instructions from the lander. The lander itself, however, was a "hazard" to the rover—we didn't want it to get entangled in the airbag material, for example. According to Andrew Mishkin at JPL, who was responsible for the sequence software on board *Sojourner*, the rover would have tried to return to the lander from its last known location (south of the rock named Chimp, about 13 meters from the lander). Then it would have tried to go around the lander in a counterclockwise direction. Errors in the rover's position would accumulate (from events such as wheel slippage, for example), so where the rover "thought" the lander was would change over time and as distance traversed increased.

If it didn't cease functioning right away, the rover ultimately could leave a spiral trail as it circled the spot where it thought the lander was. In the most wildly optimistic scenario imaginable, if *Sojourner* was still moving even just a meter or so laterally in a day, it could have traversed as much as a few kilometers in the past 10 years. The scenario is intriguing but not realistic given that *Sojourner*'s nominal life expectancy was only seven days (it was still working nearly three months after landing) and that its solar-powered energy source and electronics would have endured many cold winters with the Sun low in the sky at Ares Vallis.

Although it wasn't likely that the rover was far from the lander, I wanted to be certain, so I spent a few days carefully searching the HiRISE image in an ever-widening spiral outward from the lander. What was I looking for? Within 50–100 meters of the lander, I could compare most of the candidate "rover" features in the HiRISE image with rocks imaged by IMP. Beyond that distance, much of the terrain was hidden from *Pathfinder*'s view, so the number of rover-size features that can't be verified from the ground panoramas increased dramatically. The only way to verify a candidate feature at this distance from the lander was to see if the feature moved between HiRISE images or if it had moved recently enough that we could identify tracks leading up to it.



Left: This MOC image of the area surrounding* Opportunity*'s landing site was taken on April 26, 2004, during the rover's 91st sol, the first day of its extended mission. The rover is visible in this image, which was taken from nearly 400 kilometers (250 miles) away. Below: These three close-up views of the spacecraft's parts are cropped out and enlarged from a larger HiRISE image taken on November 14, 2006. It was easy for MOC to find* Spirit *and* Opportunity*'s components right after the spacecraft landed because they were still dust free and higher in contrast to the planet's surface. *Images: NASA/JPL/MSSS/University of Arizona*



I searched a circle with a radius of 500 meters around the lander and found nothing obvious. Just six meters south of the lander, however, we found a feature that is about the right size, where there were no sizable rocks imaged by IMP. If this is *Sojourner*, it appears to have ceased functioning not long after the lander failed, or it stayed near the lander as it was programmed to do and simply wound up at that location. We do not see tracks, so we assume *Sojourner* hasn't moved in a relatively long time. It may take even higher resolution images from orbit, or a return to the *Pathfinder* site on the surface, to verify that we have indeed found *Sojourner*.

Implications for Locating Other Landers

The HiRISE images have shown us that we can positively identify landers, rovers, and other hardware from Mars orbit, particularly when we have ground panoramas from those vehicles. But what about landers that failed to return data from the surface? For HiRISE to capture images of these, we first need to know where on Mars to look and what to expect at those locations from images at HiRISE resolution.

Judging from the landing sites so far, our best chance of identifying one of these vehicles is finding the backshell and parachute, if the vehicle had them and they deployed successfully during descent. I suggest this approach for searching because, with the exception of the *Viking 2* lander, all of the successful landers' parachutes are bright objects in the HiRISE images, even though most of us expected the *Viking* parachutes, and possibly even those of *Mars Pathfinder*, to be obscured by dust after several Martian years.

It is likely that the *Mars Polar Lander* and *Beagle 2* parachutes, if they deployed, would still be bright. Perhaps even the Soviet Mars landers, if their landing ellipses can be narrowed down, will be located by their parachutes. Of the three Soviet Mars landers, *Mars 2* is believed to have crashed and its parachute not to have deployed. Both *Mars 3* and *Mars 6* are thought to have deployed their parachutes successfully and reached the surface. Unless their locations can be narrowed down, however, the search area for these vehicles is so large that it would require hundreds of HiRISE images to cover each landing region. Nevertheless, the search has begun, and it will be interesting to see what HiRISE reveals at these sites.

From Orbit *and* from the Ground

Each time we are able to closely correlate Mars orbiter data with the "ground truth" we receive from landers, we improve our ability to decipher the complex geology of Mars. The orbiter images show us the big picture of a landing site—how the site differs from nearby locations, what processes shaped the environment, and how a particular site ties in with our global understanding of the planet. In turn, our discoveries from the surface help us to better interpret orbiter data, which then leads to a better understanding of Mars as a whole.

Additionally, this process of connecting data from orbiters and landers helps us to choose future landing sites that will be both safe for our landing systems and geologically interesting during surface operations. As we have done since the time of the *Viking* orbiters, we will continue to use our powerful "eyes" in the sky to find ourselves on Mars.

Timothy J. Parker is a planetary scientist working at the Jet Propulsion Laboratory. He is a member of the Athena science team on the Mars Exploration Rovers, a coinvestigator on the Mars Science Laboratory rover science cameras, and a member of the Mars Landing Site Selection Steering Committee.

World Watch

by Louis D. Friedman

Tokyo—The Japanese Aerospace Exploration Agency (JAXA) has announced that *Kaguya*, the lunar orbiter mission, will launch on August 16. The mission, formerly known as *SELENE*, includes two subsatellites that will help produce gravity maps of the Moon—an important step in being able to make precision landings for future robotic and human missions.

Kaguya's main orbiter includes a high-definition camera that, according to Japanese sources, is primarily for educational and public interest uses. The camera, which belongs to the Japanese television company NHK, could capture some great images of the Moon, including past lunar landers.

Washington, D.C.—The U.S. Congress is in the middle of its consideration of the NASA budget for fiscal year 2008 (which begins October 2007). Planetary Society members are aware of our efforts to reverse cuts to NASA's science budget, as proposed by the administration. One year ago, we were well on our way to success, but then the Congress abruptly ended its consideration of the 2007 budget after last year's congressional elections.

This year, we are again making progress. The House of Representatives Appropriations Committee approved a total of $17.6 billion for NASA, 1.6 percent above the administration's request. Most of this increase was for science—a victory for the Society's SOS (Save Our Science!) campaign. The committee approved additional funding to enable Europa mission development and full funding for robotic Mars mission development. It also restarted the Space Interferometry Mission, which the administration had indefinitely delayed.

The House committee paid particular attention to Earth science and climate change, reversing actions of the past six years that downplayed the value of Earth observation. A recent U.S. National Academy of Sciences report urged greater attention to Earth observing missions and specifically noted that both NASA and NOAA had cut back on plans for important Earth monitoring.

As we go to press, the full Appropriations Committee has yet to act. After it does, the bill will go to the full House for its vote.

The U.S. Senate Appropriations Committee also passed a bill with a budget increase for NASA, for a total of $17.46 billion. Although science funding saw an increase of $138 million, $30 million was cut from the request for Mars exploration. Most of that cut was designated for the Mars Exploration Rovers, which have been working successfully for the past three years.

Final action by the Congress will require votes in the full House and Senate. The houses then will need to reconcile their separate versions of the budget bill. Keep an eye on *planetary.org* for the latest information and what you can do to support NASA science and exploration.

Washington, D.C.—At the U.S. Congress' behest, NASA prepared a report on how to detect and deter near-Earth objects (NEOs) that pose a danger of colliding with Earth. The report focuses on observing, tracking, and cataloging NEOs and also investigates technologies for deflecting any asteroid found to be headed our way.

There are essentially three methods of deflecting an Earth-bound NEO: a nuclear explosion, a hard kinetic impact, and a "slow push" or gravitational tug with a low-thrust spacecraft. The NASA report characterized the nuclear option as the most effective, the kinetic as the most mature, and the slow push as the most expensive. This conclusion has been strongly criticized by some, including former astronaut Rusty Schweickart, who leads the B612 Foundation, which is dedicated to NEO deflection issues.

If an asteroid has to be moved quickly to avoid a collision with Earth, only a large nuclear explosion will provide sufficient force for the deflection. Many fear using nuclear weapons to move asteroids, especially when there are more benign options, such as deflecting an asteroid with a massive object or slowly pushing an asteroid into a new orbit. But both of these safer methods require longer lead time.

The NASA report also considered what would need to be done to find 90 percent of potentially hazardous objects by the year 2020. The report found that with current Earth observing systems, less than 15 percent of such objects will be found by 2020. New ground-based telescopes for NEO observing could raise this number to 70–75 percent, but getting near the goal of 90 percent will require a dedicated spacecraft.

The Planetary Society is aiding in these efforts through our Shoemaker NEO Grants, which fund observation and tracking of NEOs. In addition, in February 2007, The Planetary Society cosponsored a planetary defense conference that concluded that the space agencies should "research, characterize, and demonstrate technologies associated with the most promising impulsive and slow-push techniques." The conference also endorsed the Society's Apophis Mission Design Competition as a step in learning how to conduct deflection missions.

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

Celebrating the Past, Looking to the Future

by Susan Lendroth

On Friday, October 19, 2007, The Planetary Society, with Neil deGrasse Tyson and Bill Nye the Science Guy®, will host a lively discussion of what it means to be a citizen of planet Earth. The Society will also present two very special awards at the event, which will take place at the New York Academy of Sciences: The Cosmos Award for Outstanding Public Presentation of Science and The Thomas O. Paine Award for the Advancement of Human Exploration of Mars. The awards—which honor the accomplishments of two extraordinary individuals, Paula Apsell and Michael Malin—promote a future in which the exploration of distant worlds inspires and invigorates the people of Earth.

The Cosmos Award for Outstanding Public Presentation of Science

Engaging the public in the romance of space exploration is an integral part of The Planetary Society's mission. With his landmark television series *Cosmos*, Planetary Society cofounder Carl Sagan fueled the imaginations of millions of viewers around the world. To honor the innovators who follow in this tradition of presenting science and scientists accurately, yet in an entertaining and enthralling way, The Planetary Society created The Cosmos Award for Outstanding Public Presentation of Science. The award is presented this year to Paula S. Apsell, senior executive producer of the Emmy Award–winning series *NOVA* and *NOVA scienceNOW*, as well as director of the WGBH Science Unit at WGBH Boston.

Apsell joined WGBH's science documentary series *NOVA* in 1975 and has helped guide the program to its position as America's most popular science series on television and online. During her tenure, she has directed the series' diversification into other media, including its online presence on the PBS website as well as on iTunes and YouTube. *NOVA* is also the most widely used television series among high school teachers in classrooms across the country.

NOVA will continue to delve into a wide spectrum of scientific topics in its upcoming season with a program lineup that includes *Secrets of the* Sputnik *Race*, *Ghosts in Your Genes*, and *Polar Dinos*.

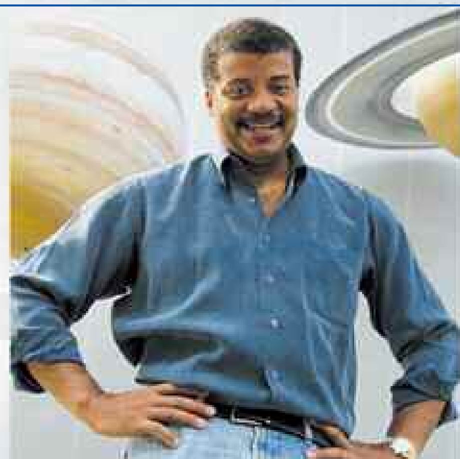
The TV newsmagazine *NOVA scienceNOW* was launched two years ago and is hosted by The Planetary Society's president, Neil deGrasse Tyson. Other recent signature *NOVA* and Science Unit productions include *The Elegant Universe*, *Origins*, *Einstein's Big Idea*, *Forgotten Genius*, and the large-format feature *Shackleton's Antarctic Adventure*.

Paula S. Apsell will receive this year's Cosmos Award for Outstanding Public Presentation of Science. Apsell is the senior executive producer of the Emmy Award–winning series* NOVA *and* NOVA scienceNOW*, as well as director of the WGBH Science Unit at Public Broadcasting System station WGBH in Boston.

Photo: Courtesy of WGBH

This still from the* NOVA scienceNOW *episode "Space Elevator," which aired in January 2007, shows Julie Bellrose and her team from the University of Michigan during their run in the Space Elevator Games at the XPRIZE Cup in Las Cruces, New Mexico.

Photo: Anna Lee Strachan, WGBH



Planetary Society President and* NOVA scienceNOW *host Neil deGrasse Tyson.

Photo: © Chris Cassidy for NOVA scienceNOW

Apsell has received several awards for her work, including the Bradford Washburn Award from the Museum of Science, Boston; the Carl Sagan Award given by the Council of Scientific Society Presidents; and the American Institute of Physics Andrew Gemant Award.

This latest award to Apsell, The Cosmos Award, has been given only once before, in 2005, to filmmaker James Cameron. The award, made possible with a grant from the M.R. and Evelyn Hudson Foundation, recognized Cameron for his IMAX science documentaries and his skill in conveying to his audiences the excitement of exploration.

The Thomas O. Paine Award for the Advancement of Human Exploration of Mars

Named in honor of Tom Paine, a member of The Planetary Society's Board of Directors for many years and NASA administrator at the time of the *Apollo 11* Moon landing, the award recognizes the group or individual who has done the most to advance the long-range human exploration of Mars. The Planetary Society takes great pleasure in honoring Michael C. Malin, president and chief scientist of Malin Space Science Systems, Inc., with this year's Thomas O. Paine Award.

Anyone who has looked at a NASA orbital image of Mars taken in the past 10 years probably has been taken on a vicarious journey to the Red Planet by Mike Malin. Not only was he the principal investigator on the Mars Orbiter Camera on *Mars Global Surveyor*, but his company also built the system that returned these thousands of remarkable images. Among the most exciting discoveries from that treasure trove of data was photographic evidence that suggested water has recently flowed on the surface of Mars.

In addition to his work on *Mars Global Surveyor*, Malin has been involved with several other missions to Mars, including the *Mars Reconnaissance Orbiter*, which is currently surveying the planet. He is the descent imaging lead for the upcoming *Phoenix* mission, and he is responsible for the testing, calibration, and operation of the mission's Mars Descent Imager, which was built by his company.

NASA recognized Malin's extraordinary contributions to Mars research with the NASA Exceptional Scientific Achievement Medal in 2002. Malin was also awarded a MacArthur Fellowship in 1987. The John D. and Catherine T. MacArthur Foundation awards between 20 and 40 MacArthur Fellowships each year to citizens or residents of the United States who demonstrate great creativity and promise.

Past recipients of the Paine Award include the U.S. and Soviet members of the *Apollo-Soyuz* crew; Daniel Goldin, then administrator of NASA; Chris McKay, a planetary scientist at NASA Research Center and now Planetary Society Board member; members of the *Mars Pathfinder* and *Mars Global Surveyor* teams; science fiction author Ray Bradbury; and, posthumously, Planetary Society cofounder Carl Sagan.

For more information, or if you are interested in purchasing tickets for this event and the reception that follows, please e-mail me at *susan.lendroth@planetary.org* or call me at (626) 793-5100, extension 237.

Susan Lendroth is manager of events and communications at The Planetary Society.

Michael C. Malin, President and Chief Scientist of Malin Space Science Systems, is the recipient of this year's Thomas O. Paine Award for the Advancement of Human Exploration of Mars.

Photo: Courtesy of M. Malin

The* Mars Global Surveyor (MGS) *was launched in November 1996. The spacecraft reached Mars in September 1997. During its decade of operations, its Mars Orbiter Camera (MOC) returned more than 240,000 amazing images of the Red Planet—not bad considering that* MGS*' primary mission, at the time of launch, was scheduled to end in early 2000. This mosaic view is composed of wide-angle camera daily global mapping images taken in October 2006. Two annular (somewhat circular) clouds are visible at upper left, and Mars' north polar cap is visible at center right. Annular clouds are common in midnorthern summer in Mars' north polar region, and they may result from eddy currents in the lower atmosphere. Such clouds appear yearly; this year they came like clockwork within a two-week forecast period, based on the previous four Martian years of experience gained from* MGS *MOC daily global imaging. Despite the superficial resemblance to Earth-orbiting satellite views of hurricanes, these cloud features are not the result of strong winds, and they typically dissipate later in the day.

Image: NASA/JPL/Malin Space Science Systems

OCEANS IN THE OUTER SOLA
—AND NO

Left: The distant
casts its weak lig
over a frozen lan
scape in this artis
interpretation of
Europa's icy surf
Illustration: Kees Veen

by Robert Pappalardo

On Earth, everywhere there is water, there is life, so it is reasonable that the search for life in our solar system focuses on the search for water. The presence of water will indicate the best places to continue the search for life. If we find life, we will try to understand why it was able to take hold; just as important, if life is absent, we will want to know why.

The solar system's most promising candidate for an ocean beyond the Earth lies beneath the icy surface of Jupiter's moon Europa. Europa is one of the most geophysically and astrobiologically fascinating bodies in our planetary neighborhood. Its exploration is key to advancing our understanding of habitable zones in our own—and other—solar systems.

Oceans might exist below the surface of other icy satellites as well, including Ganymede, Titan, Triton, and perhaps even tiny Enceladus. Here, we will take a tour that focuses on Europa but will also visit other icy bodies and the possible oceans within.

Oceans Come and Go

The frigid outer solar system is rich in ice. Not only water ice is plentiful, but also carbon dioxide, nitrogen, and methane ices, and possibly ammonia-water ice compounds. Generally, the more exotic ices are more abundant farther from the Sun, where it is colder and more volatile compounds can freeze out. Within the clement interiors of ice-rich moons, it can be warm enough for ices to melt into oceans.

Notions of oceans within icy satellites have come and gone—and come back again, in recent years—as our scientific understanding has evolved. In the early 1970s, John Lewis and Guy Consolmagno realized that internal heat might be sufficient to melt oceans within icy moons, at least early in the solar system's history. However, in 1979, Ray Reynolds and Pat Cassen seemed to spoil the "swimming party." They realized that the icy shell that caps an internal ocean will thicken as the satellite loses heat over geologic time, eventually reaching a critical thickness at

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In Europa's chaos terrain, city-sized ice blocks have split, drifted, and tilted into a rubbly and slushy matrix, now frozen solid. This* Galileo *image of chaotic terrain suggests that Europa's ice shell has undergone at least partial melting. *Image: NASA/JPL, reprocessed by Ryan Sicilia*

Europa's surface is crisscrossed by ridges, including Rhadamanthys Linea, which cuts diagonally across this* Galileo *image from the upper left to lower right. A younger cycloidal ridge transects the region from lower left toward the right. Pits and dark spots (each about 10 kilometers, or 6 miles, across) pepper the icy surface, probably related to blobs of warm ice that rise from within the icy shell. *Image: NASA/JPL, reprocessed by Ryan Sicilia*

which its ice will convect. When convection occurs, warm ice at the base of the floating ice shell moves buoyantly upward, and cold ice near the top of the ice shell sinks downward, like wax within a lava lamp. They calculated that convection of ice would cause a satellite to lose heat very rapidly, freezing an internal ocean in about 100 million years. Even if many moons once had oceans, it seemed that they should be frozen solid today.

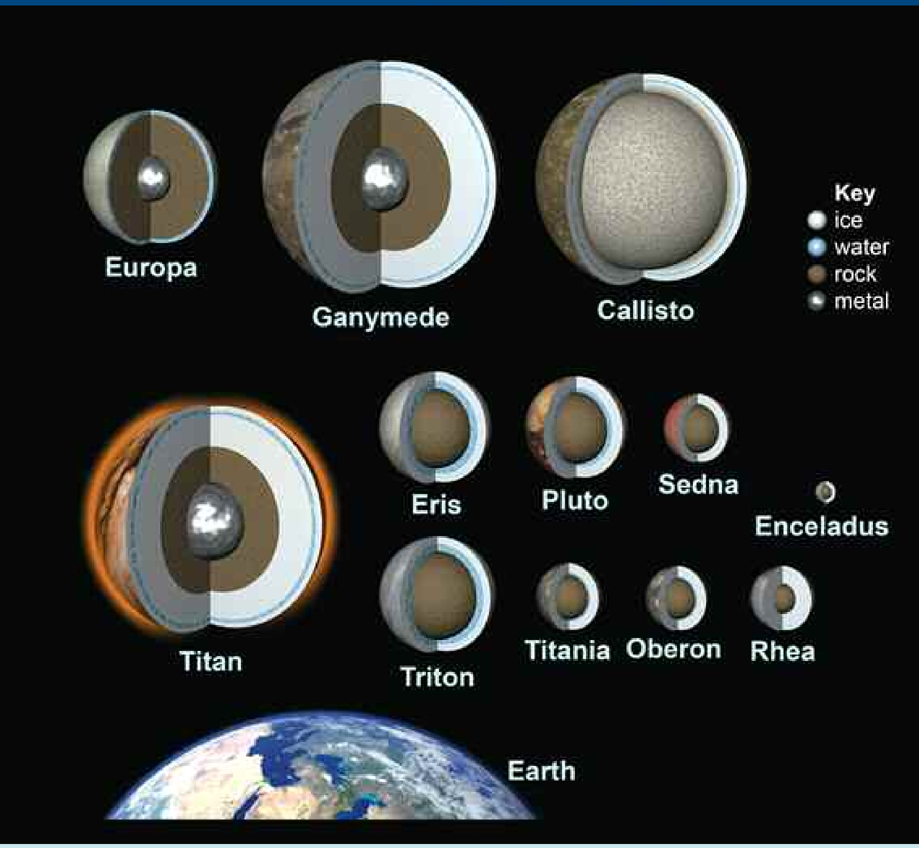
Later calculations performed in the 1980s indicated that tidal heating might change the story, for Europa at least. It seemed that Europa might generate enough internal heat, as it orbits Jupiter and is squeezed by the giant planet's gravity, that it might maintain an ocean beneath its icy surface layer. This prediction set the stage for the *Galileo* mission.

Ocean "Sandwiches": Ganymede and Callisto

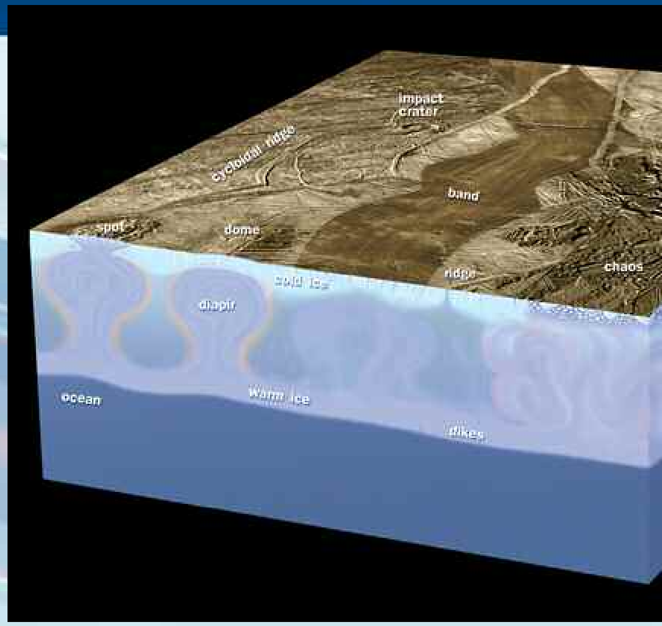
The ocean story was reopened by an unlikely player: the heavily cratered, seemingly dead Jovian moon Callisto. During the *Galileo* spacecraft's third orbit of Jupiter in 1996, the magnetometer aboard *Galileo* showed that there was something strange going on: the observations suggested that Callisto might have a magnetic field of its own. The data from a later flyby of Callisto, however, did not fit the predictions from the earlier orbit. Instead, it appeared as if the magnetic field near Callisto had flipped from north to south. These magnetic field data are best explained if Callisto is generating a local magnetic field that counters the external magnetic field of its parent planet, Jupiter. This can happen only if the moon contains a conducting layer beneath its surface.

Jupiter's magnetic field is tilted by about 10 degrees compared with the equatorial plane in which its moons orbit. As Jupiter rotates rapidly, with a 10-hour period, its magnetic field rotates too. Because of the magnetic field's tilt, Jupiter's moons alternately find themselves above the magnetic equator of Jupiter, then below, then above again. This means that the moons feel Jupiter's magnetic field alternating in polarity on a time scale of several hours as Jupiter rotates. If there is a conducting layer within Callisto, the moon could generate a magnetic field that opposes Jupiter's alternating magnetic field, explaining the observations. The only material that reasonably could compose such a layer is saltwater. Callisto's induced magnetic field tells us that there must be an ocean within.

That a geologically cold and dead moon such as Callisto has an ocean seems strange at first, but Callisto's interior contains enough rock that the heat from radioactive decay alone allows it to maintain an ocean. Some sort of antifreeze would help as well, such as salts that



As many as 13 of the known planetary bodies in our solar system may contain oceans. Jupiter's ice-coated moons (Europa, Ganymede, and Callisto) probably contain internal saltwater oceans. The more distant large and medium-sized icy moons, the icy dwarf planets, and tiny Enceladus may contain colder ammonia-water oceans. Oceans in icy satellites could be a common feature throughout the universe, while Earth's surface ocean may be the more unusual case. Illustration: Doug Ellison, Emily Lakdawalla, and Robert Pappalardo



Europa's bizarre surface features suggest a churning, icy interior. Ice blobs rising from the warm base of the floating ice shell to the cold and cracked near-surface ice could create surface spots, domes, dark bands, and chaos. A large impact with bull's-eye rings may have punched all the way through the ice shell to the ocean. Churning ice blobs may allow surface oxidants to reach the ocean and allow signs of oceanic material—including life, if it exists there—to be found at the surface. Illustration: NASA/JPL

lower the melting temperature of ice, in the same way that salts help to melt the ice from a wintry sidewalk.

Ganymede is the solar system's only moon with its own intrinsic magnetic field, which is generated within a hot iron core. Ganymede certainly has had a much hotter and more tumultuous history than Callisto. This is confirmed by gravity data from *Galileo*, which indicate that Ganymede is layered, with an iron core, a rocky mantle, and an H_2O-rich crust about 900 kilometers (560 miles) thick. The *Galileo* magnetometer data show that Ganymede also has an induced magnetic field, implying that an internal ocean lurks within its thick ice crust. This discovery came late in the *Galileo* mission, because the induced magnetic field signal is weak compared with the powerful intrinsic magnetic field of Ganymede.

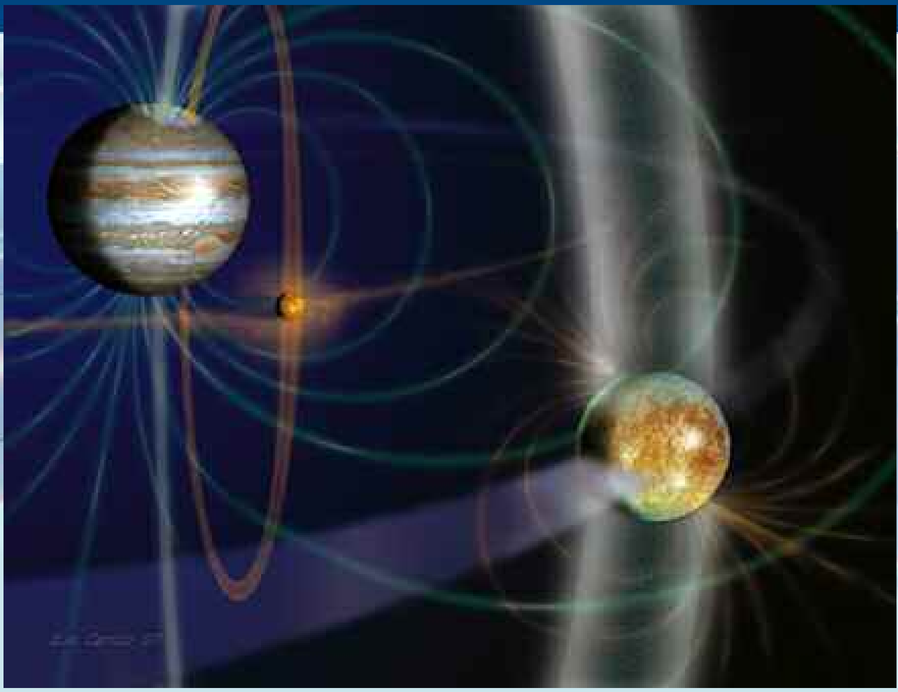
Because these moons contain thick ice layers, the salty oceans of Callisto and Ganymede must be sandwiched or perched between layers of ordinary ice above and higher-density forms of ice below, at predicted depths of about 150 kilometers (90 miles) within the moons. These oceans suggest that liquid water might be common in large icy moons. They might not contain the chemical nutrients necessary for life to metabolize and survive, however, because they are in contact only with ice above and below, instead of chemically complex rock. Geologic processes such as large impacts in the distant past may have brought these oceans into contact with the surface only rarely.

Europa's Ocean

Gravity data tell us that Europa's interior is layered, with an iron core and rocky mantle, topped by an H_2O-rich layer only about 100 kilometers (60 miles) thick. The last close flyby of Europa by the *Galileo* spacecraft in 2000 confirmed the existence of an induced magnetic field, indicating a subsurface ocean. Europa's thin H_2O layer, unlike conditions on its sibling satellites, means that pressures never get high enough for high-density ices to form beneath the ocean. This means that Europa's salty ocean is not sandwiched between ice layers but is in direct contact with a rocky mantle below.

A rocky seafloor means that the chemical nutrients that might support life can be leached directly from the rocky mantle. Nutrients might even spew from hydrothermal vents, places where water seeps into the mantle below and comes into contact with hot rock, in turn pouring chemical-rich water back into the ocean. At such "black smokers" on Earth's ocean floors, life is exotic and plentiful.

The arcing cracks and ridges on Europa's surface trace patterns that tell of an ocean below. Most of the solar system's moons are in synchronous rotation, with their face always directed to their parent planets as they



A complex, invisible interplay of magnetic fields shapes the Jovian system. Jupiter's powerful rotating magnetic field generates an induced magnetic field at Europa, betraying the presence of the satellite's subsurface ocean. Also, fast-moving ions trapped in Jupiter's magnetosphere slam into Europa, splitting water to create oxygen that could fuel life in the ocean.
Illustration: Michael Carroll

orbit. Europa's patterns of fractures instead suggest that the stresses that formed them have resulted in part from slow slippage of the ice shell over the deeper interior. Thus, the ice shell rotates at a rate slightly faster than synchronous, and it takes perhaps 10 million years for the ice shell to slip once around over the interior. This nonsynchronous rotation requires a lubricating layer, as an ocean would provide.

Europa's orbit is somewhat elliptical, so it experiences a changing gravitational pull from its enormous parent planet as it orbits Jupiter each 3.55 Earth days. This means that the tides Europa experiences should cause the ice shell to flex by about 30 meters (100 feet) as it orbits, about the height of a seven-story building. This flexing means that the stresses at a given point on the surface can continually change direction as Europa orbits. The strange arcing of many fractures and ridges on Europa probably is related to formation of the cracks in this ever-changing stress environment. Indirectly, then, these arcing features betray a hidden ocean.

Europa's Surface

The formation of Europa's ubiquitous ridges is probably related to the rise of water or warm ice along cracks. One model suggests that ridges are produced as the opposing sides of faults in the icy surface grind back and forth against each other, generating heat (much like rubbing your hands together) and perhaps melting ice along ridges.

The wider dark bands on Europa may be places where the ice shell has spread apart, exposing warmer icy material from below. They may be icy analogues to the spreading centers that exist on Earth's rocky ocean floors, with new ice spewing out along a central axis.

Europa's face is freckled by pits, domes, and dark spots collectively known as *lenticulae*, which is Latin for "freckles." Individual lenticulae are commonly about 10 kilometers (6 miles) across, and they often pockmark the surface in clusters. They suggest that Europa's ice shell is convecting, as Reynolds and Cassen had first predicted. Blobs of warm ice apparently have risen up from the base of the floating ice shell; some have impinged on the cold surface layer, warping it upward into domes, and others have pierced the cold icy shell to flow out onto the surface.

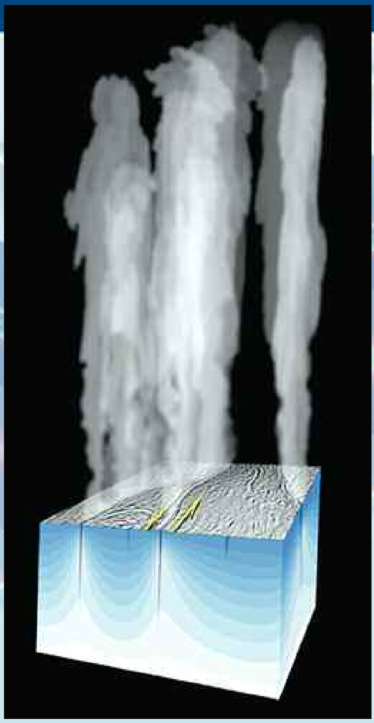
Europa shows large disrupted regions, aptly named *chaos*, where the surface is broken into raftlike plates that have rotated and tilted in a sea of rubbly debris. Some planetary scientists believe these are places where the ice shell has completely melted, perhaps above a warm plume of water below. Others believe that in these sites, ice convection has been especially intense, ripping and shredding the cold ice above and partially melting shallow ice to allow fragmented blocks to slide around, as if upon the upraised hands of an enthusiastic crowd. Either way, chaos tells of a warm and active ice shell, with communication between the surface and the ocean either directly by melting or indirectly through convection.

Reynolds and Cassen had predicted that convection should rapidly freeze an ocean, but the magnetic data tell us that Europa's ocean is still there. In recent decades, significant advances have been made in understanding convection, tidal heating, and the properties of ice. It now seems that ice convection might not freeze an underlying ocean, but instead ice convection and a tidally heated ocean can coexist through time.

The Spring of Youth

Most remarkable about the surface of Europa is its

Plumes of water vapor spew from fractures near the south pole of Saturn's moon Enceladus, backlit by sunlight streaming through. Planetary scientists were astounded to find current activity on such a small, icy moon. The water vapor hints at a subsurface ocean, probably related to tidal heating resulting from the squeezing of Enceladus during its elliptical orbit about Saturn.
Image: NASA/JPL



The "shear heating" model suggests that tidal squeezing of Enceladus' icy shell causes the sides of the faults to rub back and forth against each other, producing enough heat to transform some ice into plumes of water vapor and ice crystals. Cold subsurface ice (blue) becomes much warmer near the active fractures from which the plumes emanate.
Illustration: NASA/JPL

youth. The presence of only a very few large impact craters indicates that the surface is young, with an average age of about 60 million years. Much of Europa's surface activity has transpired in the geologically short time since dinosaurs ruled the Earth.

The thickness of Europa's ice shell is uncertain, but geology provides clues. Consideration of the amount of tidal and radiogenic heat from Europa leads to predictions of an ice shell 20 to 30 kilometers (12 to 19 miles) thick. Convection is predicted to begin somewhere within this range of ice shell thicknesses. Most telling, Europa's two largest impact structures show concentric rings, like a bull's-eye, formed when a giant impact punched all the way through the ice shell. Huge ancient ring systems are seen on Ganymede and Callisto, indicating that their ice shells were about 100 kilometers (60 miles) thick in the distant past. Europa's smaller and geologically recent bull's-eye rings indicate an ice shell about 20 kilometers (12 miles) thick today.

Europa's intense geologic activity and thin ice shell combine to give its ocean an advantage that other icy satellite oceans do not have: the churning and perhaps melting of its ice shell allows the ocean and surface to exchange water and ice. This provides an important advantage for life, because nutrients are created at Europa's surface by the same radiation that would rip apart any organisms that might accidentally find themselves there.

Europa's surface is bathed in the intense radiation from high-energy charged particles trapped in Jupiter's magnetic field. These particles slam into Europa's ice-rich surface, transforming some of its H_2O into molecules of oxygen (O_2), hydrogen peroxide (H_2O_2), and other oxidized compounds. Europa's surface radiation would quickly kill any organisms at the surface, but if these oxidants can find their way into the subsurface ocean, they would make an ideal chemical fuel for life. This is especially true if black smokers supply complementary reduced compounds into Europa's ocean from below.

Europa's geologic activity and thin ice shell may permit life to exist in the lightless depths of its subsurface ocean. If life does exist there, then convection or melting can transport that life to the surface. Life cannot survive on the surface because of the intense radiation of Jupiter's charged particles, but its chemical signatures might be detectable with an orbiting or landed spacecraft that uses the right techniques.

Oceans 13?

With the discovery of oceans within the large icy moons of Jupiter comes the realization that oceans may exist within the solar system's many other large and medium-sized moons. Water could even exist within the largest icy dwarf planets, including Pluto and recently discovered Eris and Sedna. When Earth is included in the tally, as many as 13 known solar system bodies could include oceans.

Just a few of the solar system's icy moons experience significant tidal heating today, so the main source of heat is from radioactive decay, which is unable to raise internal temperatures of small icy objects very high for very long. Nevertheless, at distances from the Sun of Saturn or beyond, even medium-sized moons could have oceans if they contain some ammonia. Ice made from a combination of H_2O and ammonia melts at a much lower temperature than pure H_2O ice alone. H_2O ice melts at 0 degrees Celsius (32 degrees Fahrenheit), but adding ammonia reduces the melting temperature to –100 degrees Celsius (–148 degrees Fahrenheit). Recent work by Hauke Hussman and colleagues shows that this could allow a moon as small as Oberon at Uranus or Rhea at Saturn to melt out and retain an ammonia-water ocean.

Saturn's large moon Titan probably contains a lot of ammonia and is large enough to have significant radioactive heating, so it is almost certain to have an internal ammonia-water ocean. This is in addition to its surface seas of ethane and methane, recently discovered by the *Cassini* spacecraft. The depth and thickness of the internal Titan ocean are uncertain and are subjects of active research.

Neptune's large moon Triton contains many exotic ices, and it is probably large enough to melt an ammonia-water ocean from radiogenic heating alone. But Triton stands out in its potential for a subsurface ocean because its retrograde orbit indicates that it must have been captured into orbit about Neptune. Soon after capture, Triton must have experienced extreme tidal heating, enough to melt a thick ocean. Its surface geology tells of past intense activity, with an average surface age of just 100 million years. It is uncertain when in solar system history Triton's capture took place, but a youthful surface means that an ocean probably still lurks within Triton today.

Saturn's tiny moon Enceladus offered a surprise when the *Cassini* spacecraft found that the moon's south polar region is much hotter than expected, with jets of water vapor streaming from its surface. The energy source must somehow lie in tidal heating of Enceladus as it orbits Saturn. The warm surface leads some planetary scientists to hypothesize that pockets of water exist in the shallow subsurface of Enceladus, perhaps only a few tens of meters down. Alternatively, heat may be generated as tidal flexing causes the opposing sides of faults in the icy surface to grind back and forth against each other, similar to a model for explaining ridges on Europa. This would permit frictional heat to vaporize ice, producing the escaping plumes and warm surface. Either way, an ocean or sea may lie deep within Enceladus. This may be a warm and long-lasting ocean or a cold and ephemeral ammonia-water sea, perhaps related to a temporary spike in the moon's tidal heating. Further *Cassini* observations will add to our understanding of the source of the Enceladus plumes and the implications for liquid water.

Could a cold ammonia-water ocean be a fruitful place for life? At low temperatures, the chemical reactions that power life are sluggish, and life as we know it on Earth is poisoned by ammonia. Whether alien life could exist in an ammonia-rich ocean remains a topic of speculation.

The amount of chemical energy needed to support life in internal oceans is also quite uncertain. Oceans within some large icy bodies, including Callisto, Ganymede, Titan, and perhaps Triton, would be sandwiched between layers of ice above and below, so they may not contain the chemical nutrients necessary to sustain life. If oceans exist within medium-sized icy moons, they are in direct contact with rock, but only very limited chemical energy can enter their oceans because these moons are probably not geologically active today.

Europa and the Search for Life

Europa is a rare place, arguably offering the best prospect for present-day life in our solar system beyond Earth. Europa's warm, salty ocean is in direct contact with a mantle that could be geologically active, supplying chemical nutrients from below. Its ice shell is relatively thin and its surface is youthful, so recent or current activity could churn nutrients downward into the ocean, and life (if it exists) could be exposed at the surface.

The search for life on Europa will begin slowly and requires patience. Following the example of the recent successful missions to Mars, an orbiting spacecraft is the first step in evaluating the habitability of Europa. The *Europa Explorer* spacecraft now on the drawing boards will be able to characterize Europa's ocean, including its thickness and salinity, using gravity, altimetry, and magnetometry. Ice-penetrating radar will search for pockets of shallow water within the ice shell, such as in chaos regions and along ridges, and radar might even be able to penetrate all the way to the ocean. Compositional measurements, imaging, and charged particle readings will combine to indicate how Europa's surface features are created and evolve, and whether the moon's chemistry is conducive to life. If NASA decides to fund the *Europa Explorer* soon, it could launch by 2015, reach Jupiter by 2021, and enter Europa's orbit by 2023.

In the even more distant future, humans will land a spacecraft on Europa. A lander might be able to directly sample the chemical makeup of the surface and could use a seismometer to directly measure the ice thickness. Using sophisticated chemical analyses and a simple microscope, it could look for signs of life.

Europa is at the top of the short list of planetary bodies that motivate the search for water and life beyond Earth. In the outer solar system and the universe beyond, there may be oceans in many places, but the question remains whether life exists that can imbibe this elixir. In exploring Europa, we will put a metaphorical toe in the ocean water, exploring our solar system's most promising example of an icy satellite habitat.

Robert Pappalardo is a principal scientist at the Jet Propulsion Laboratory. His research focuses on processes that shape the surfaces of icy satellites and implications for satellites' interiors and histories.

We Make It Happen!

by Bruce Betts

As a Planetary Society member, your name is one step closer to Mars. The silica glass mini-DVD with a quarter-million names on it (including yours) has been installed on the *Phoenix* spacecraft, and the spacecraft is at Cape Canaveral awaiting launch to Mars! The launch period opens on August 3, and NASA has about three weeks in which to launch *Phoenix* toward the Red Planet.

The Content

In addition to the quarter-million names, the disc also contains *Visions of Mars*, a collection of literature and art about the Red Planet. Your name joins the greats of science fiction and Mars science history on the DVD, which includes works by Isaac Asimov, Ray Bradbury, Arthur C. Clarke, and many more in fiction, as well as the historical works of Schiaparelli and Percival Lowell, among others. The disc also includes greetings to future human explorers of Mars delivered by Carl Sagan, Arthur C. Clarke, Judith Merrill, and the Society's own Louis Friedman. We are truly sending the first library to Mars!

You can find pictures of the installed DVD and more information about Visions of Mars at *planetary.org/programs/projects/messages/20070523.html*. You can also print a certificate with your name on it documenting your inclusion on the disc.

The DVD and the Spacecraft

The data were written to the special silica mini-DVD by Plasmon OMS, and we received engineering support for the disc from Visionary Products, Inc., which also engineered the DVDs on the landers that delivered the Mars Exploration Rovers. The resulting archival disc should last at least a few hundred years on the Martian surface, waiting to be picked up by future explorers. They will recognize it because a special label was applied to the disc. After the data were written to the disc and the label was applied, the whole assembly was baked out (to kill microbes and also to reduce future outgassing of the materials) and installed onto the spacecraft by Lockheed Martin.

After further testing and assembly, the spacecraft was shipped to Cape Canaveral in May in preparation for its August launch to Mars. *Phoenix* will land in the northern near-polar regions in late May or early June 2008 (the exact landing date will depend on the launch date).

The Mission

Phoenix is an independently selected NASA Mars Scout mission. *Phoenix*

What's Up?

In the Sky—August and September

A total lunar eclipse is scheduled for August 27–28, visible from most of eastern Asia, Australia, and the Americas. A partial solar eclipse on September 11 will be visible from most of central and southern South America. See *sunearth.gsfc.nasa.gov/eclipse/* for more information on either eclipse. Jupiter is the brightest starlike object in the west in the early evening. It is near the Moon on August 21. Reddish Mars rises higher in the predawn east over time. During September, a very bright Venus will appear low in the pre-dawn east, then, later in the month, dimmer Saturn will appear. The annual Perseid meteor shower will peak on August 13.

Random Space Fact

If the Sun were six feet (just under two meters) in diameter, then Earth's diameter would be about that of a marble (about 0.7 inches, or 1.7 centimeters), and it would be 645 feet (197 meters) away.

Trivia Contest

Our March/April contest winner is Ric D. T. Wilson of Middle Camberwell, Australia. Congratulations!

The Question was: Who discovered Pluto?

The Answer: Clyde Tombaugh

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

What was the second spacecraft to fly by Jupiter?

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Submissions must be received by October 1, 2007. The winner will be chosen by a random drawing from among all the correct entries received.

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will be the first lander to explore the Martian arctic. It is a fixed lander with a suite of advanced instruments and a robotic arm that will dig into the subsurface half a meter to a meter to study the water ice the mission expects to find. *Phoenix* will uncover clues in the Martian arctic soils about the history of water on Mars and the potential for habitability.

The mission is led by Principal Investigator Peter Smith of the University of Arizona, with project management at NASA's Jet Propulsion Laboratory and development partnership with Lockheed Martin Space Systems. International contributions for *Phoenix* are being provided by the Canadian Space Agency, the University of Neuchatel (Switzerland), the University of Copenhagen, and the Max Planck Institute in Germany.

We'll keep you informed on the mission as it progresses toward launch, and we'll update you on the launch and landing. After landing, the disc will appear in calibration images from the camera, so we should have images of "you" on the surface soon after landing. On to Mars!

The* Phoenix *DVD was installed on the deck of the* Phoenix *lander on April 3, 2007, at the Multipurpose Test Facility at the Lockheed Martin Waterton Plant in Denver, Colorado.

Photo: NASA/JPL/Lockheed Martin

Bruce Betts is director of projects at The Planetary Society.

Society News

Planetary Society Board Changes Shape

In the last few months, we've made changes to our leadership. I am pleased to announce that our Board of Directors has elected Neil deGrasse Tyson as the new president of The Planetary Society. Neil has been Board chair for the past three years, but as president, he will take a more direct role in setting Society policy and direction. Other good news is that Bill Nye the Science Guy® will continue as vice president. Bill is extraordinarily popular as a communicator of the "Passion, Beauty, and Joy" (PB&J) of science.

Our new Board chair is Dan Geraci, who has served as a director for four years and is a longtime space aficionado. He has been a great supporter of the Society and brings to us expertise from the world of finance and business. Dan was also the chief sponsor of our Apophis Competition.

With the election of Neil, Bill, and Dan as key leaders, along with directors such as Jim Bell, Heidi Hammel, Elon Musk, and George Yancopolous, the Society has taken an important step in making the transition of the Society from the generation of its founders (Carl Sagan, Bruce Murray, and I) to a generation of successors. Of course, Bruce and I are still involved, and Wes Huntress, Chris McKay, Joe Ryan, and Steven Spielberg still serve on the Board.

With regret and understanding, we accepted the resignation of Ann Druyan from our board of directors. Ann has been part of the Society since our founding, both through the collaboration with her husband and our cofounder Carl Sagan and in her own right after the untimely death of Carl in 1996. Her media company, Cosmos Studios, has been and remains our partner in conducting the world's first solar sail mission, *Cosmos 1*. Her resignation allows the business dealings between the Society and Cosmos Studios to be completely clean and independent, as we vigorously pursue the development of a *Cosmos 2* solar sail. We wish her the best of luck and thank her deeply for her longtime love and support of The Planetary Society.

—Louis D. Friedman, Executive Director

Chairman of The Planetary Society of Japan Dies

On May 31, 2007, Tamiya Nomura, chairman of The Planetary Society of Japan, passed away at the age of 83. Nomura, the former high commissioner of the Space Activities Commission in Japan, headed The Planetary Society of Japan since its inception in 1999.

Nomura was born in Tokyo in 1923 and began his career as an assistant professor at The Institute for Research in Productivity at the University of Tokyo. Shortly after Hideo Itokawa formed the team of AVSA (Avionics and Supersonic Aerodynamics) at the institute, Nomura joined it; he spent the rest of his life working on Japan's space development.

When The Planetary Society of Japan was established at the end of 1999, Nomura stepped in to lead the new organization. The mission of The Planetary Society of Japan is to provide the means for the citizens of Japan to share their interest in and support for space exploration and the search for extraterrestrial life.

—LDF

Questions and Answers

Because* Dawn *will be traveling in the main asteroid belt, it seems like it should be able to do some flybys of other asteroids besides Ceres and Vesta, though they might be distant. Will* Dawn *visit any other asteroids? If so, which ones?
—Phil Stooke
University of Western Ontario, Canada

Let me begin with a little background information. For a mission using ion propulsion, the trajectory is intimately connected with details of the spacecraft's performance—quite unlike the trajectory for a standard chemical propulsion mission. Conventional missions coast most of the way from Earth to their destinations. With ion propulsion, however, the spacecraft spends much of its time in powered flight, yielding vastly more control over its trajectory. Hence, with ion propulsion, spacecraft may be sent on missions that otherwise would be unaffordable or impossible for other vehicles.

The amount of electrical power the spacecraft can supply to the ion propulsion system throughout the mission determines how effective the thrusting is and how much thrusting it needs to do. (Higher power provides both higher thrust and more fuel-efficient thrust.) Our design has been based on conservative calculations of how much electricity *Dawn*'s solar arrays will produce and how much power all its other subsystems will consume, and thus how much will be available for the ion propulsion system. Until *Dawn* is in space, however, we will not know the actual values. For example, how much heater power a spacecraft will require is very difficult to predict with great accuracy; although we conducted extensive tests in a thermal vacuum chamber, we still have some level of uncertainty.

For this and other reasons, the actual trajectory likely will change as we refine our understanding of the details of the spacecraft's performance, and the corresponding changes in the spacecraft's path to its destinations can be much greater than one might expect from missions that use chemical propulsion. (By the way, the unique flexibility of the ion propulsion means our Vesta and Ceres rendezvous dates and our Vesta departure date may shift by several months or even more.) As a result, we have not found it productive to investigate bonus asteroid encounters. Once we are in flight, we will know the initial trajectory (as determined by the day and time of launch), and after we have completed the 80-day commissioning of the spacecraft, we certainly will look for encounter opportunities. We do not know now what the options might be nor how much additional thrusting might be required to alter the trajectory to accomplish a flyby.

It is also worth noting that Ceres and Vesta are quite unlike the overwhelming majority of residents of the asteroid belt. *Dawn*'s destinations are the two most massive bodies in the asteroid belt, and they completely dwarf even the largest asteroid ever encountered by a spacecraft. I think of Ceres and Vesta as being among the last unexplored worlds in the inner solar system. Although we have much flexibility in our trajectory, we would like to translate as much of it as we can into additional time in orbit around Vesta, for which our scientific instruments are optimized. Although an asteroid flyby would be both interesting and exciting, the scientific return would have to be weighed against the benefit of devoting more time to scrutinizing Vesta before we have to depart for Ceres.
—MARC D. RAYMAN,
Jet Propulsion Laboratory

Dawn will visit Ceres and Vesta—the two largest objects in the asteroid belt—to search for answers to questions about the formation of our solar system. The mission is scheduled to launch in September of this year.
Illustration: William K. Hartmann, courtesy of the University of California, Los Angeles

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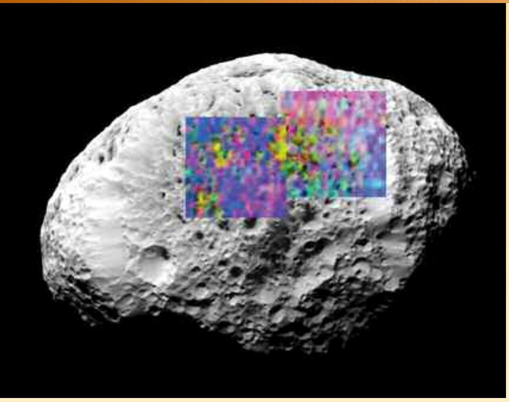

Cassini ***has detected some of the basic chemicals necessary for the formation of life on the surface of Saturn's moon Hyperion. This map portrays the composition of a portion of the satellite's surface. Blue shows frozen water, red indicates carbon dioxide (CO_2) ice, magenta reveals regions of water plus CO_2 ice, and yellow is a mix of CO_2 and some unidentified material.*** *Image: NASA/JPL/University of Arizona/Space Science Institute*

The basic chemicals necessary for life have been discovered on Saturn's moon Hyperion. Images returned by *Cassini* have revealed for the first time details of Hyperion's surface, including cuplike craters filled with hydrocarbons (see image above). When *Cassini* flew past Hyperion in September 2005, its instruments detected water and carbon dioxide ices, as well as dark material that fits the spectral profile of hydrocarbons.

"Of special interest is the presence on Hyperion of hydrocarbons—combinations of carbon and hydrogen atoms that are found in comets, meteorites, and the dust in our galaxy," said Dale Cruikshank of NASA's Ames Research Center. "These molecules, when embedded in ice and exposed to ultraviolet light, form new molecules of biological significance. This doesn't mean that we have found life, but it is a further indication that the basic chemistry needed for life is widespread in the universe.

"Most of Hyperion's surface ice is a mix of frozen water and organic dust, but carbon dioxide ice is also prominent," explained Cruikshank. "The carbon dioxide is not pure, but is somehow chemically attached to other molecules. We think that ordinary carbon dioxide will evaporate from Saturn's moons over long periods of time," Cruikshank said, "but it appears to be much more stable when it is attached to other molecules." Cruikshank is the lead author of a paper detailing these findings in the July 5, 2007 issue of *Nature*.
—from NASA

Saturn's moons Tethys and Dione are flinging great streams of particles into space, according to data from *Cassini*. The discovery suggests the possibility of some sort of geologic activity, perhaps even volcanic, on these icy worlds. The particles (known as *plasma*) were traced to the two moons because of the dramatic outward movement of electrically charged gas, which could be mapped back to the moons' orbits in the magnetic environment of Saturn. Soon after *Cassini* reached Saturn in June 2004, its instruments revealed that the planet's rapid rotation squashes the plasma into a disc, and that great fingers of gas are being thrown out into space from the disc's outer edges.

Now *Cassini* team member Jim Burch of the Southwest Research Institute and his colleagues have found that the direction of the ejected electrons points back toward Tethys and Dione. "It establishes Tethys and Dione as important sources of plasma in Saturn's magnetosphere," said Burch. Until this discovery, the only moons of Saturn known to be active worlds were Titan and Enceladus.

Burch and his colleagues reported on their discovery in the June 14, 2007 issue of *Nature*.
—from NASA

LATE-BREAKING NEWS! NASA Plans New Discovery Missions

As we neared press time, NASA announced that it will use the *Deep Impact* and *Stardust* spacecraft to perform new observations—previously unplanned investigations of comets and extrasolar planets.

"These mission extensions are as exciting as it gets," said Alan Stern, associate administrator for NASA's Science Mission Directorate. "They will allow us to revisit a comet for the first time, add another to the list of comets explored, and make a search for small planets around stars with known large planets. And by using existing spacecraft in flight, we can accomplish all of this for only about 15 percent of the cost of starting a new mission from scratch. These new mission assignments for veteran spacecraft represent not only creative thinking and planning but also a prime example of getting more from the budget we have."

The EPOXI mission will meld two projects: the Deep Impact Extended Investigation (DIXI) and the Extrasolar Planet Observation and Characterization (EPOCh). Both projects will use the *Deep Impact* flyby spacecraft, which finished its prime mission in 2005. DIXI will be targeted to fly by comet Boethin on December 5, 2008. Boethin is a small, short-period comet that has never been explored.

EPOCh will observe several nearby bright stars, watching as the giant planets already known to be orbiting the stars pass in front of and then behind them. The collected data will be used to characterize the planets and to determine whether they possess rings, moons, or Earth-sized planetary companions. This search for extrasolar planets will be made this year, en route to comet Boethin. EPOCh's sensitivity will exceed that of both current ground- and space-based observatories. EPOCh also will measure the mid-infrared spectrum of Earth, providing comparative data for future efforts to study the atmospheres of extrasolar planets.

The other newly selected mission of opportunity is called New Exploration of Tempel 1 (NExT). The mission will reuse the *Stardust* spacecraft to revisit comet Tempel 1. This investigation will provide the first look at the changes to a comet nucleus produced after its close approach to the Sun. NExT also will extend the mapping of Tempel 1, studying its "geology" where bright material appears to have flowed like liquid or powder. NExT is scheduled to fly by Tempel 1 on February 14, 2011.

Members' Dialogue

More of Why We Explore Space

I agree with the statements made by Marcus Prazniak and Luciano Fleishfresser in the March/April 2007 issue of *The Planetary Report*.

I want to shout loudly from the bottom of my heart: "What if I could walk on the Moon? What would I see and find there? How would I feel gravity on the surface of Mars? How can we design a spacesuit that will endure the extreme heat, pressure, and noxious gas on the surface of Venus? What would I find on other planets if I could go there?"

These are wishes that all people embrace. Therefore, I would dare to state that our desire to explore space is our biological instinct, not just a curiosity of childhood.
—MITSURE YAMADA,
Isesaki-City, Gunma, Japan

This is a question often asked—especially when there is a paradigm shift in space exploration. A simplistic answer is always "because it's there." An idealistic answer, posed as a question, might be, "Are we alone?" A more practical answer might be, "Because some of the space research will enable us to test and understand more accurately the models of Earth's climate in the past, the present, and, hopefully, the future."

On a more personal level, the fan in the pursuit of learning on any space topic enjoys the awe, wonder, and excitement of discovery.
—DENNIS BLANCHARD,
San Jose, California

In answer to the question "Why do we explore space?" I refer you to a quote from the novel *Lucifer's Hammer* by Robert A. Heinlein: "The Earth is just too small and fragile a basket for the human race to keep all its eggs in."
—TOMMY LANCASTER,
Pasadena, Texas

From the smallest known species to the largest on this planet, there is one common characteristic, and that is the conquering of space. When a species can no longer conquer its space, it becomes extinct.

Humans, the sentient beings, are aware of far more space than other living creatures, and so conquering of that space is essential to our very life. To cease to conquer space (by *conquer* I do not mean to subjugate, I mean be able to control) is to cease to live to one's fullest. It applies to the individual in a single life as it applies to humans, the species, over the progress of generations. It is not as immediately obvious a matter of survival as taking a breath to live, but in the long run it is no less important.

We explore or we become extinct. Humankind is a causative species—it makes things happen. If we don't explore, things will "happen" to us. It's cause or effect. I choose cause. Most people do. Let's go!
—NICK FRASER,
Clearwater, Florida

We explore space to return, to reconnect with our past, and to lay claim to our boundless future. This calling is not a choice as much as a mandate and resides deep within each of our timeless souls. To heed this call is to claim our rightful destiny and to develop beyond measure.
—MICHAEL L. TURNEY,
Diamond Springs, California

On Mars and Metrics

When I e-mailed the *Rosetta* image of Mars reproduced in the March/April 2007 issue of *The Planetary Report* to a friend, he replied, "That's one of the coolest pictures I've ever seen from space! [It] reminds me of an illustration by Chesley Bonestell, only it's real." I agree. Bonestell would be proud.

The inside cover's "background" caption reads "the scarp is up to six kilometers (35 miles) high." I'm guessing that's a typo—a typo that came from mixing international and American units of measure. I'm a strong supporter of The Planetary Society and its goals but it continues to perplex me that *The Planetary Report* still uses mixed measures.
—PATRICK WIGGINS,
Tooele, Utah

The conversion should read "about 3.5 miles."
—Editor

Erratum:

Our May/June 2007 issue has an error on page 22 (Society News). In the "Save the Date" note, the day and date of the New York event should read "Friday, October 19."
—Editor

Please send your letters to
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Fire and Ice, Bettina Forget's diptych of Io and Europa, reminds us that the surfaces of these Jovian moons stand out as two of the more distinctive and painterly of the worlds in our planetary neighborhood. Forget carved a description of Io's hot, sulfurous surface along the curves of its lava flows in Sütterlin, an old form of German handwriting. To describe Europa's icy surface, she used Sütterlin again, but she covered the words with a thin layer of white paint to make them look frozen.

Bettina Forget, originally from Hamburg, Germany, lives and works in Montreal, Canada. Her work has been exhibited in solo and group shows, as well as private collections in Montreal, Singapore, London, and Perth, Australia, to name a few.

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