The PLANETARY REPORT

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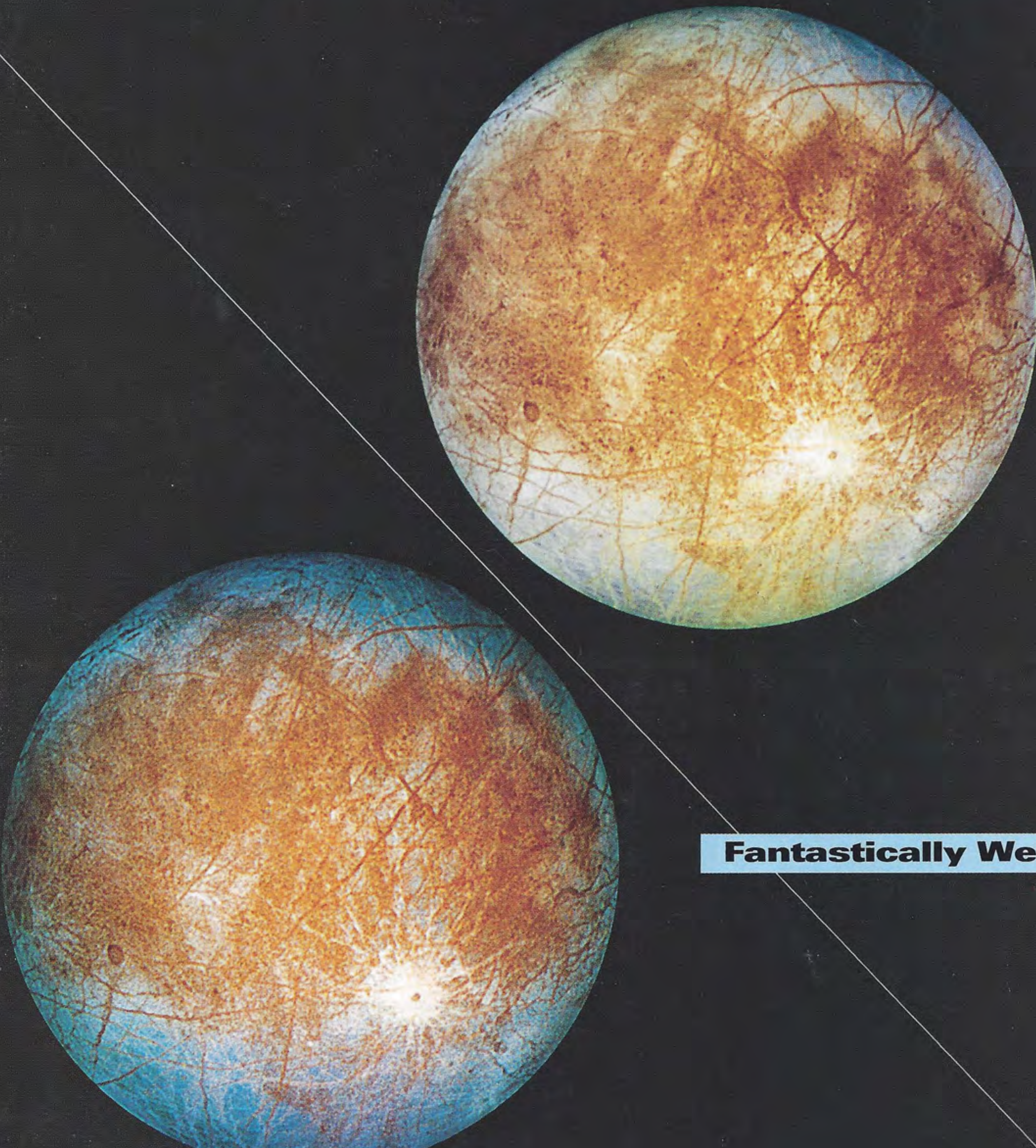

Fantastically Weird

On the Cover:

"Fantastically weird" slipped out as geologist Jim Head described the latest *Galileo* images of Europa. This is one of the most enigmatic worlds yet seen by spacecraft, and the closer we look, the stranger it gets. It may possess an ocean beneath a water-ice crust, perhaps hiding a potential habitat for life. Here we show the moon as it appeared from 677,000 kilometers (420,000 miles) away last September during *Galileo*'s flyby of Ganymede. At left is a false-color image, with contrasts enhanced to bring out compositional differences in the primarily ice crust. At right is a natural-color image, showing Europa as it might appear to an observer riding the spacecraft. Images: JPL/NASA

From The Editor

The theme has pervaded the space program since its birth, sometimes playing softly in the background, other times forcefully dominating missions and programs. That theme is, of course, life in the universe. With *Galileo* circling closer and closer to Europa, spacecraft flying to Mars, and powerful telescopes finding more and more planets around other stars, the theme is once again gaining power.

NASA has committed to extending *Galileo*'s funding to cover the Europa Extended Mission, in the hopes of determining if an ocean lies beneath its icy surface. Both NASA and the National Science Foundation are encouraging research to determine if the meteorite ALH84001 does hold traces of ancient Martian life. Returning a sample of Mars to Earth has gained priority in NASA's plans for the next century. And questions concerning extrasolar planets have shifted from "Do they exist?" to "Which ones might support life?"

This is a time of fantastic opportunity for the Planetary Society to reach an increasingly receptive audience with our message. The only way to find life on other worlds is to explore them. It's our job to make that happen.
—Charlene M. Anderson

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Members' **Dialogue**

Another option?

Soon after hearing about the demise of the *Mars '96* mission I realized that the microdot with Planetary Society members' names was lost too, and I was saddened even further. I urge the Society to approach NASA with a proposal to refly the lost microdot and the *Visions of Mars* CD-ROM on the 1998 Mars Surveyor lander mission. The opportunity to have one's name fly to the Red Planet on a robotic explorer is a very romantic notion indeed. I hope that you will soon be approaching NASA to suggest the inclusion of these important "payloads."
—JOEL W. POWELL,
Calgary, Alberta, Canada

It is too late and probably technically impossible to put Visions of Mars *on the 1998 Mars Surveyor lander. That mission has very tight weight and volume constraints. The CD also contains material particular to* Mars '96 *and should be changed to fly on another mission. The small stations, on which were mounted the CD and the special Society label with the radiation recorder and our members' names, is being considered for flight in 2001 as part of "Mars Together." We will certainly discuss this with NASA and the Russian Space Agency as an idea for Mars landers in 2001 or later.*
—Louis D. Friedman, Executive Director

Don't privatize

I disagree with Donald Brewer's optimism concerning the privatization of space agencies. (See the November/December 1996 *Planetary Report.*) He expresses a desire to be rid of the endless government bureaucracies involved in space exploration. But I believe that privatization will replace the endless government problems with endless business problems.

I think government involvement at this time is good. This allows the motives to be set more by people than by profit. A private company is under no obligation to listen to voters. It would pay more heed to markets and backers. A government-supported private company could turn its attention from survival and business to what people in general are interested in doing. But such a company is no longer free from government or private bureaucracies.

Things should stay as they are until it's more reasonable for private citizens to undertake businesses involved with being in space.
—PAUL RICHMAN,
Vancouver, British Columbia, Canada

Inspiration

Although I am frequently struck with awe by the photographs presented in your magazine and often moved by the wonderful example of cooperative effort between the public and professionals (and even policy-makers) that the Planetary Society represents, I often feel despair at humanity's inability to fix goals that extend beyond our own lives, beyond our personal gain. But in my frustration-darkened sky, there is sometimes a reentry vehicle of inspiration.

The gesture made by Jane Rigby in donating a portion of her Geraldine R. Dodge Foundation award to Project BETA (see the November/December 1996 Members' Dialogue) is a reminder to us all of the best humanity has to offer and why, eventually, we may be worthy representatives of our planet in whatever community the universe has to offer.
—EVAN MALONE,
Philadelphia, Pennsylvania

Praise

Thank you for existing—for remaining a strong voice, always informing and enlightening the public about the many wonders of our solar system and beyond. I appreciate the fact that the Society has spoken to those in our government to ensure that they are made aware of the great importance of such experiments as the Mars Balloon. I thank your organization, Louis Friedman, and Carl Sagan for your continued hard work and for sharing it with those who are interested.
—SHAWNA MERLIN BURCH, *Boise, Idaho*

NASA's Budget

Regarding the issue of spending NASA's money on social projects rather than on space exploration, consider this: if Queen Isabella had taken the money she gave Christopher Columbus and invested it in social projects instead, just imagine the utopia Spain would be today.
—E. R. LEIBFRITZ,
San Jose, California

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Waltzing by Mathilde: NEAR's First Asteroid Encounter

by Robert W. Farquhar and Donald K. Yeomans

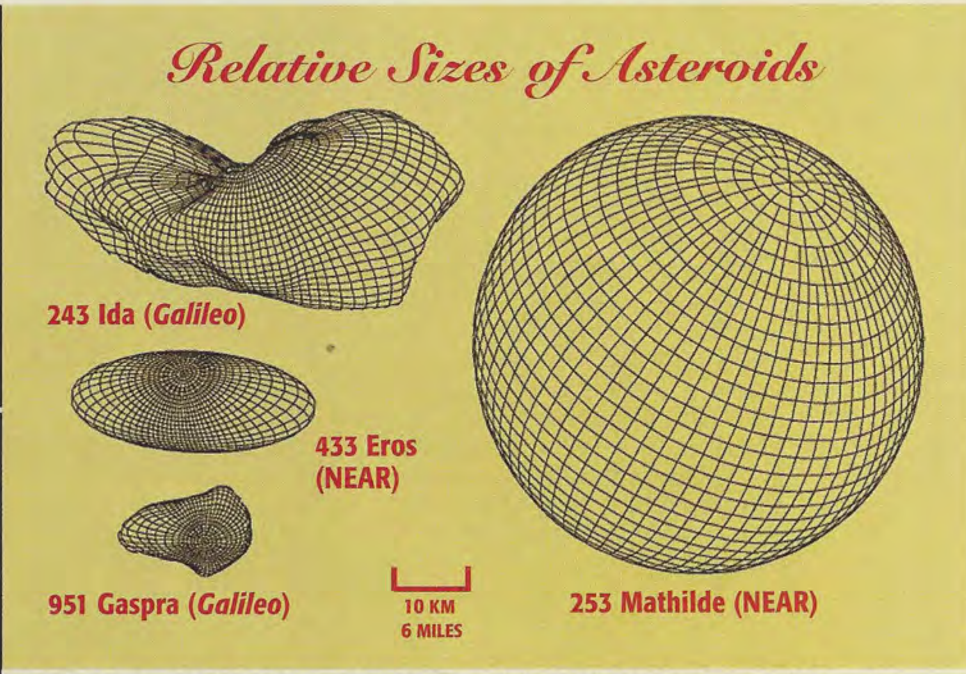
The Near-Earth Asteroid Rendezvous spacecraft flies past Mathilde, collecting information on this dark, slowly rotating object discovered more than 100 years ago. After leaving Mathilde, NEAR will continue on to rendezvous with the asteroid Eros. Illustration: Michael Carroll

253 Mathilde

Dimensions:	50 x 50 x 70 kilometers 30 x 30 x 40 miles
Class:	C (Carbon Rich)
Rotation Period:	17.4 days

Orbit:

Perihelion:	1.94 AU
Aphelion:	3.35 AU
Inclination:	6.7 degrees
Orbital Period:	4.31 years



***Top left:* *On August 28, 1993,* Galileo *passed by Ida, an irregularly shaped asteroid in the main belt between the orbits of Mars and Jupiter. Mathilde is much larger than either of the asteroids visited by* Galileo.**

Left: Gaspra was the first asteroid to be scrutinized close up by a spacecraft—and thus by the humans looking through the spacecraft's cameras.* Galileo *flew by Gaspra on October 29, 1991 on its way to the Jupiter system.

Images: JPL/NASA; Illustration: Peter Thomas

Late in 1994, only one year before the launch of the Near-Earth Asteroid Rendezvous (NEAR) spacecraft, there was a bit of turmoil within the flight project. Mission designers had discovered that the trajectory to asteroid Eros would take the spacecraft closely by a large asteroid named Mathilde. Should we make plans to have NEAR observe this large asteroid? To do so would use up precious fuel and further complicate an already complex mission plan. Risks would increase because the spacecraft was custom-made to orbit asteroid Eros, not fly by Mathilde, and the spacecraft's observations might require more power than its solar panels could provide.

Even worse, dust particles orbiting Mathilde might destroy the spacecraft as it flew past at 10 kilometers per second—ten times faster than a rifle shot.

Some argued that the risks were too high and the prudent thing to do was to ignore the potential June 1997 flyby of Mathilde. After all, the NEAR spacecraft would spend nearly a year in orbit around the asteroid Eros, and the *Galileo* spacecraft had already studied two asteroids, Gaspra and Ida. Was it worth the risks to fly closely past yet another asteroid? Was Mathilde so out of the ordinary that well developed mission plans should be changed? Could we make discoveries during this asteroid flyby that hadn't already been made during the Gaspra and Ida flybys? The answers turned out to be yes, yes, and yes.

Asteroid 253 Mathilde

Asteroid 253 Mathilde was discovered on November 12, 1885 by Johann Palisa in Vienna, Austria. The asteroid name was suggested by V. A. Lebeuf, the staff member of the Paris Observatory who first computed an orbit for the new asteroid. The name Mathilde is thought to honor the wife of astronomer Moritz Loewy, then the vice director of the Paris Observatory. Although the asteroid's existence has been known since 1885, it was only following the announcement of NEAR's possible flyby that astronomers made extensive physical observations using telescopes on Earth. These showed that far from being a garden-variety asteroid, Mathilde is an extremely unusual object.

To date, the only spacecraft encounters with asteroids have been the *Galileo* flybys of 951 Gaspra in October 1991 and 243 Ida in August 1993. Both objects are S-type asteroids, the most common asteroid type in the inner part of the asteroid belt (the region between the orbits of Mars and Jupiter, littered with rocky bodies too small to be considered planets). Asteroid 433 Eros, NEAR's destination, is also an S-type asteroid. However, the most common type of asteroid in the outer asteroid belt, comprising the dark and primitive C-type objects, has yet to be investigated by spacecraft. Spectral observations by Richard Binzel and his colleagues show that Mathilde is a C-type asteroid—and a big one at that. Its spectrum falls between those of the two largest asteroids known, 1 Ceres and 2 Pallas. Mathilde is twice the size of Ida and four times the size of Gaspra. And because it reflects only 4 percent of the light falling upon it, Mathilde is one of the blackest objects in the solar system.

Mathilde's slow spin is another intriguing characteristic. Using a series of observations from the first half of 1995, Stefano Mottola and his colleagues determined that its rotation period is an extremely long 17.4 days. Only two asteroids, 288 Glauke and 1220 Clocus, have longer periods (48 and 31 days, respectively), and there is no obvious mechanism to account for these extremely long asteroid "days." Collisions by neighboring asteroids could be enough to slow an asteroid's spin, but statistically it is very unlikely that a

Asteroid Eros: The Primary Target

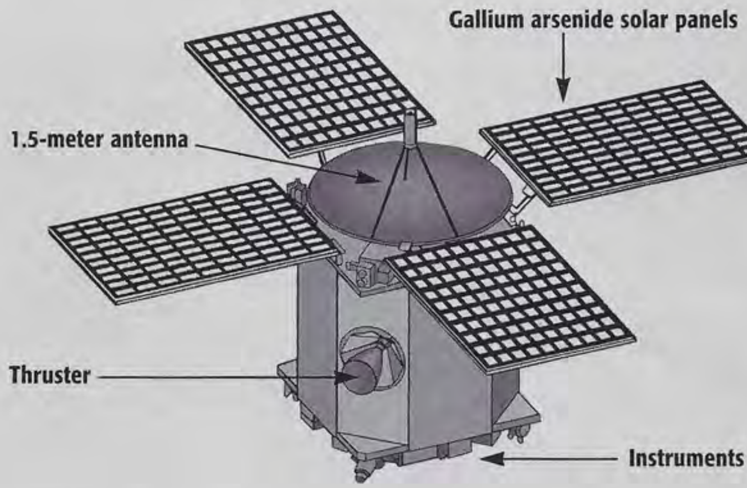
On February 17, 1996, a Delta 2 rocket launched the Near-Earth Asteroid Rendezvous (NEAR) spacecraft toward its encounters with two very different asteroids. NEAR is the first mission in NASA's Discovery program for "faster, cheaper, better" planetary exploration. Simplicity and low cost were the main considerations in the design of the NEAR spacecraft. The science instruments, solar panels, and the high-gain antenna are mounted to the body of the spacecraft rather than on a movable platform. Although this configuration increases the complexity of spacecraft operations, it was an important factor in overall cost containment. NEAR's development cost totaled less than $125 million in real-year dollars—well under the Discovery cost cap of $150 million in Fiscal Year 1992 dollars.

The primary objective of the NEAR mission is to orbit the large near-Earth asteroid 433 Eros. All previous encounters with asteroids have been quick flybys. From this vantage point in orbit, NEAR will make the first comprehensive investigation of an asteroid's physical properties and surface composition. The multispectral camera will map Eros's form and color variations at 3-meter resolution. Mineral properties of Eros's surface will be mapped at 250-meter resolution with the near-infrared spectrometer. X-ray and gamma-ray spectrometers will measure the abundances of several key elements in the surface layer, including aluminum, magnesium, iron, calcium, sulfur, thorium, and potassium. These abundances will then be matched to those of a variety of meteorite samples on Earth to ascertain whether this type of asteroid could be the source for certain meteorite types. The magnetometer will address the question of whether Eros has a magnetic field of its own. Data from the laser rangefinder (lidar) will be used to determine the shape and topography of Eros's surface to an accuracy of 10 meters. The lidar determines the precise distance to the asteroid's surface by measuring the time required for a pulse of light to travel to the asteroid's surface and return. Eros's mass and distribution of mass will be determined while the spacecraft is in orbit; spacecraft tracking measurements together with optical and lidar observations from the spacecraft will provide the necessary data.

NEAR follows a circuitous three-year flight path to Eros because of a Discovery program guideline to use an inexpensive launch vehicle. With a larger launch vehicle, such as an Atlas or Titan, a one-year direct trajectory would have been possible, but the total mission cost would have been increased by at least $50 million.

Rendezvous operations at Eros are scheduled to begin on December 20, 1998, with an initial close encounter (at a distance of 500 kilometers, or 300 miles) occurring on January 10, 1999. Later, as the spacecraft is maneuvered closer to Eros, NEAR will conduct science investigations from orbits that come as close as 15 kilometers (9 miles). In the last two months of orbit, the minimum altitude will be lowered still further. Finally, on February 6, 2000, NEAR will attempt a soft landing on Eros. Since the NEAR spacecraft was not designed to survive a landing, this maneuver should mark the end of the NEAR mission. By Valentine's Day in 2000, NEAR will become a permanent fixture on the asteroid named for the Greek god of love. *—RWF and DKY*

NEAR Spacecraft Summary



Science Payload:
- **Multispectral imager**
- **Near-infrared spectrometer**
- **X-ray spectrometer**
- **Gamma-ray spectrometer**
- **Laser altimeter**
- **Magnetometer**

Total Weight: 800 kilograms 1800 pounds
- **Propellants: 320 kilograms 710 pounds**
- **Experiments: 60 kilograms 130 pounds**

colliding body would have just the right velocity (speed *and* direction) to stop the prior spin. According to Alan Harris of the Jet Propulsion Laboratory, there is less than one chance in a billion that the spins of three asteroids should be nearly stopped by random impacts. Harris notes that the situation is analogous to asking a baseball player to bunt three fastballs so that the ball comes to a complete stop each time and drops onto the center of home plate.

An undiscovered satellite orbiting Mathilde might slow its rotation rate by tidal forces (much as our Moon affects Earth's rotation rate), but the time required for a moonlet to slow Mathilde would be longer than the age of the universe. There is something very odd about Mathilde, and the upcoming NEAR investigations should help explain its peculiarities.

Planning the Flyby

Once we established that there was only a negligible probability of the NEAR spacecraft being crippled by a collision with a particle in orbit around Mathilde and that only a modest amount of extra fuel was required, the mission team developed plans to optimize results from the fast flyby. NEAR will encounter Mathilde on June 27, 1997. At that time, NEAR will be roughly 2.0 AU from the Sun and 2.2 AU from Earth (AU = astronomical unit, the mean distance between Earth and the Sun).

The first step in planning the flyby was to determine accurately the asteroid's future path using ground-based observations of its past positions. We now have more than 500 of these observations for Mathilde over the interval from December 1, 1885 to July 23, 1996, with only 77 obtained before 1994. Using these data, a conservative error analysis suggests that the uncertainty region in Mathilde's position at the time of the NEAR flyby will have a maximum extent of about 200 kilometers (125 miles). This uncertainty can be cut in half if high-precision radar observations of Mathilde can be carried out in early June 1997.

Unfortunately, an uncertainty of 200 kilometers is far too large. The spacecraft flies past the asteroid so fast that there is little time for the onboard cameras to look around for their target. The search area must be reduced to a desired value of about 25 kilometers (16 miles). Even using the cameras to provide a pre-encounter fix on the asteroid's true position might not solve the problem, because NEAR may not be able to detect Mathilde any earlier than 24 to 36 hours before the encounter. The late detection is due to the unfavorable direction by which the spacecraft approaches Mathilde. During its approach, the spacecraft will see just a small portion of Mathilde's sunlit hemisphere so that the asteroid will appear only as a thin crescent.

Taking pictures of a small object like an asteroid during a fast flyby is extremely challenging for any spacecraft, especially one, such as NEAR, that does not have a movable camera platform. It would be like videotaping a billboard from a car that is speeding along a multi-lane highway at night. If you know exactly where the billboard is located, you could ask the driver to pass by very closely while you move the camcorder at just the proper angular rate. However, if you don't know precisely where the billboard is—or its height above the ground—you'd be better off observing from a greater distance, panning the camcorder back and forth to cover the entire region where the billboard might be located. Your optimum strategy would be to pass as close to the billboard as possible to get the best look but still keep far enough away so you could sweep the entire uncertainty region, ensuring that you would get a picture of the target.

In an analogous fashion, NEAR can get to within 1200 kilometers (750 miles) of Mathilde's predicted position and still have the ability to make the panning motions that will ensure the camera has captured a series of close-up pictures of Mathilde. Because the NEAR camera is fixed to the side of the spacecraft, the entire spacecraft, not just the camera, must slew to observe the asteroid.

Our current plans call for a spacecraft trajectory correction maneuver just 12 hours before closest approach. This maneuver will utilize spacecraft camera images of Mathilde taken up to 24 hours before the encounter and should allow us to achieve the desired targeting accuracy. However, the strategy is gutsy. The speed of the flyby does not leave much margin for error.

Since the Mathilde flyby occurs almost 2 AU from the Sun, the power available from the spacecraft's solar panels is only about 25 percent of the maximum mission level. We'll lose another chunk of available power because the solar panels, like the cameras, are fixed in position. In order for

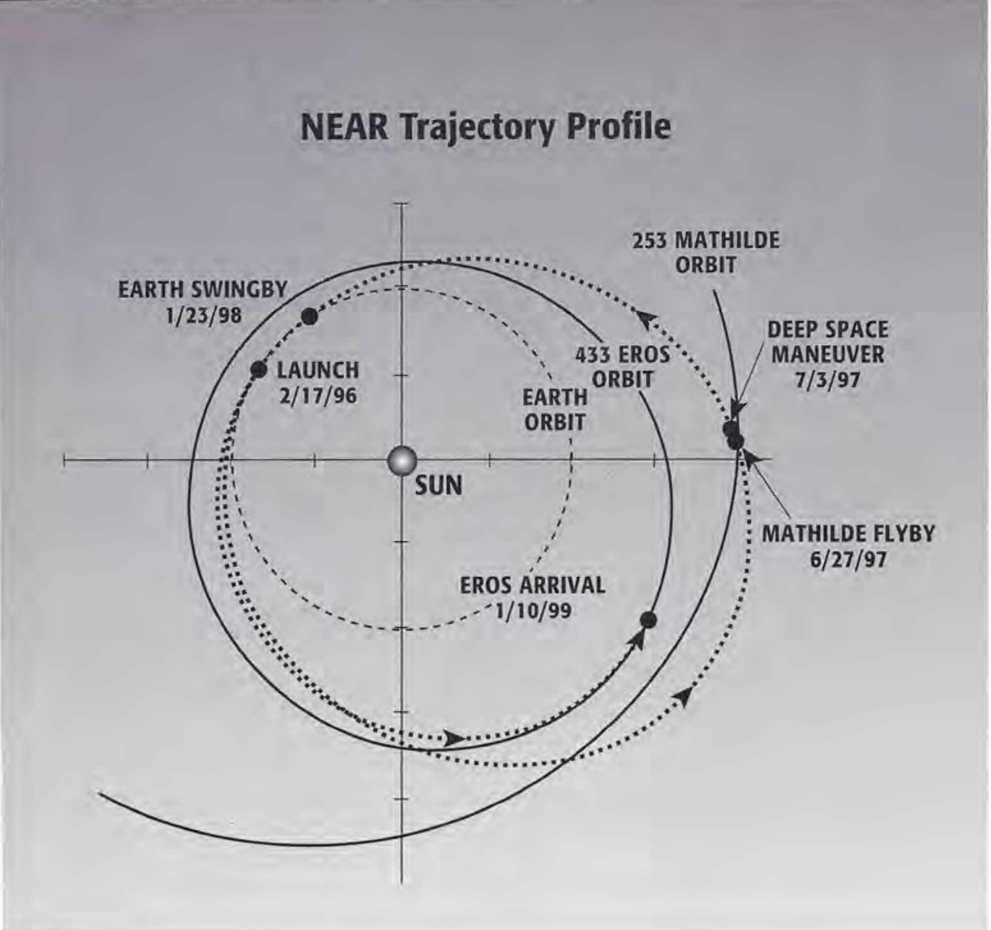
(continued on next page)

Who Cares About These Little Rocks Anyway?

In a sense, the study of asteroids is a quest for our origins. We think asteroids are leftover bits and pieces from the formation of the inner solar system planets (including Earth), a process that took place some 4.6 billion years ago. These objects may preserve clues to the nature of the material from which the terrestrial planets accreted. Asteroids are a likely source of most meteorites that strike the Earth, and some may be ex-comets that have lost the vaporizing ices that once produced their signature cometary atmospheres and tails. Asteroid collisions may have delivered to early Earth the veneer of volatiles and carbon-based molecules from which life formed. Subsequent collisions of a few good-sized asteroids with Earth could have periodically snuffed out some emerging life forms, allowing only the most adaptive species to prosper. Even today, some asteroids are on Earth-crossing orbits and offer a potential threat (albeit a very small one) to life as we know it. Despite being some of the smallest members of our solar system, these bits of interplanetary flotsam likely played a critical role in the formation of Earth and the subsequent development of life. To study asteroids is to study our own origins.

Most asteroids have been classified as so-called S-types or C-types. Astronomers classify asteroids by their ability to reflect light in various wavelengths (that is, by their spectral characteristics). The most common type in the inner part of the asteroid belt is the S-type, whose ability to reflect light generally increases as wavelength increases from 0.4 to 1.2 microns (micron = 0.000039 inch). In the outer asteroid belt, the much darker C-type asteroids dominate, and their signature is that they reflect light nearly equally at all wavelengths between 0.4 and 1.2 microns (that is, their spectra are relatively flat and featureless).

Neither the S-type nor the C-type asteroids have been definitely identified as parent bodies for any meteorites on Earth. Some scientists believe that the most common meteorites, the ordinary chondrites, originate as collision fragments from the S-type asteroids in the inner belt. Another group of scientists thinks there is no familial relationship. As a result, a major objective of the NEAR mission is to match the chemical composition of Eros against that of the ordinary chondrite meteorites or another meteorite type. The results of the NEAR mission should provide evidence as to which meteorite types, if any, began life as a piece of an S-type asteroid. —*RWF and DKY*



the camera to point at Mathilde during the flyby, the solar panels must face about 50 degrees away from the Sun. Because of this very constrained power condition the only science instrument we will operate during the encounter is the multispectral camera. However, we can use spacecraft tracking data before and after the encounter to determine the asteroid's mass.

Encounter Science

We have three major objectives for the NEAR camera experiment during the flyby. Most important is that we get at least one image of Mathilde near closest approach to provide the most detailed view possible of the surface. Our second requirement is to obtain an image that includes as much of the sunlit side as can be seen from the spacecraft's perspective. Third, we want to search the sky around the asteroid for possible satellites.

The entire imaging sequence will be accomplished within about 30 minutes of closest approach, totaling about 300 images. The cameras will image the whole illuminated portion of the asteroid in color, resolving features as small as 500 meters. The best partial views will also be in color with resolution down to 200 to 350 meters.

Another primary science objective during the flyby will be to estimate Mathilde's bulk density, a quantity that requires determining the asteroid's volume and mass. The bulk density of Mathilde is important in discerning its origin. For example, is this asteroid a single large fragment from a collision of two larger asteroids, or is it a collection of many smaller fragments—fragments that resulted from repeated collisions of many different types of asteroids? A low density for Mathilde would suggest that it was formed as a collection of several distinct fragments held loosely together like a rubble pile. A higher density, similar to solid rock, would suggest that Mathilde was formed as a chip off an old block, a fragment of a larger body that was disrupted by a collision with another asteroid eons ago.

We will use the camera system to determine the approximate shape of the asteroid and hence its volume. Unfortunately, since the asteroid rotates so slowly, it will present only one side to the passing spacecraft. We have preliminary plans to use ground-based radar to help determine the volume of the asteroid. Steve Ostro and his colleagues have demonstrated that radar observation campaigns can provide detailed information on an asteroid's size and shape.

We'll determine Mathilde's mass by accurately tracking the NEAR spacecraft before and after the encounter. During the flyby, Mathilde's gravitational attraction will exert a slight tug on the spacecraft, changing its velocity by about 3 millimeters per second (0.1 inches per second) and bending its flight path by 0.00002 degrees. One hour after the flyby, when the spacecraft has traveled another 36,000 kilometers (22,000 miles), it will have deviated only 12 meters from its nominal path. Gravitational tugs on *Galileo* were far too small to allow a mass determination for asteroids Gaspra and Ida. However, Mathilde's mass is likely to be much greater than that of either Gaspra or Ida, so its effect on the NEAR spacecraft's path should be detectable in the radio tracking data. According to a recent analysis by Dan Scheeres of the Jet Propulsion Laboratory, Mathilde's mass should be determined to an accuracy of about 5 percent.

The flyby of asteroid 253 Mathilde is an important and challenging segment of the NEAR mission. To achieve our major science objectives, we will have to continue refining our knowledge of Mathilde's orbit from precise ground-based observations. As the moment of encounter approaches, we'll have to be ready to use NEAR images of Mathilde to assure that the cameras will be properly pointed at their target at closest approach.

The Mathilde flyby will complement the *Galileo* flybys of Gaspra and Ida in important ways: it will be the first close-up study of a C-type asteroid, and it will be the first time such a study is carried out by a spacecraft without a movable camera platform. The results obtained will not only provide an important test of the NEAR camera but will permit us to assess fundamental differences that may exist between C-type asteroids and S-objects, of which NEAR's main target, 433 Eros, is representative. However, as is normally the case for interplanetary encounters, the most interesting results will take scientists completely by surprise as the NEAR spacecraft waltzes by Mathilde.

Robert W. Farquhar of the Johns Hopkins University's Applied Physics Laboratory is the NEAR Mission Director. Donald K. Yeomans of the Jet Propulsion Laboratory is the Team Leader for the NEAR Radio Science Experiment.

Farewell, Pioneer

by James D. Burke

It was March, 1972. Vietnam's agony dragged on while a fatal corruption seeped into the campaign for reelection of President Richard M. Nixon. Threatened abroad by the Soviet Union and embittered by dissension, Americans can perhaps be forgiven if we hardly noticed the launch of one more spacecraft. On March 3 began a journey like none other. For the first time in the long climb of *homo sapiens* from a mystery-shrouded past to an unknowable future, we launched an object whose ultimate destination was the stars.

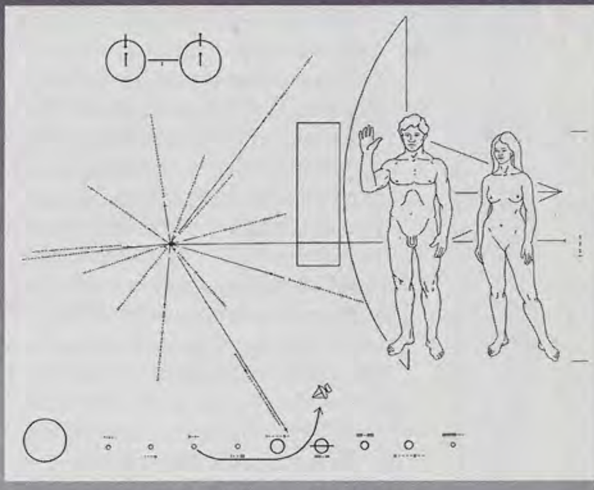
Now, 25 years later, *Pioneer 10* is the first of four such artifacts, spacecraft that have left us forever, escaping not only the gravity of Earth but also that of the Sun. With its fellows, *Pioneer 11* and *Voyagers 1* and *2,* flung onward by giant Jupiter, *Pioneer 10* is outbound to interstellar space.

During its decades of exploration *Pioneer 10* has returned reams of data about interplanetary phenomena, including the first measurements near Jupiter defining that planet's enormous magnetosphere and its deadly radiation and particle environments. Now *Pioneer 10* probes outward toward that vast, fluctuating, diaphanous edge of the solar domain where at last the ever-expanding wind of magnetism, gases, and particles from the Sun is turned back by the interstellar medium. This is the boundary of the heliosphere, the end of our neighborhood in space.

All four of our escaping emissaries are powered by plutonium, whose inexorable decay heats thermocouples to make electricity on board. Over the years this power will fade. Still, the *Voyagers* are expected to continue reduced operation well into the next century. Not so, *Pioneer 10*. Soon *Pioneer 10* will receive an irrevocable command to shut down, its funding spent, its duties ended, and its small share of tracking time on the Deep Space Network released for other uses. *Pioneer 10* will drift onward silently, its motion governed by the law of universal gravitation, while human generations come and go, and civilizations rise and fall.

Though we will probably forget *Pioneer 10* as our busy little antlike lives go on, Earth's first stellar emissary cannot forget us. In its engineering details, it will forever reveal that somewhere in the cosmos there were mathematical beings who could win and work metals, generate radio signals, and call down the Promethean fire of the nucleus. And more: *Pioneer 10* carries the first message from us, intended to prove that there was, at our time and place in the universe, an intelligence that knew something of nature and something of itself. The golden plaque, installed at the urging of Carl Sagan and drawn by Linda Salzman, rides on *Pioneer 10* toward whatever destiny awaits it in star space and time.

James D. Burke is Technical Editor of The Planetary Report.



Top: Pioneer 10 *was the first spacecraft launched on a trajectory taking it out of our solar system. Middle: On December 3, 1973,* Pioneer 10 *became the first spacecraft to fly by the planet Jupiter. Bottom: The spacecraft carries a plaque bearing a message to any civilization that might find it. Counterclockwise from top left are a schematic of a hydrogen atom, a pulsar map containing information on the location and time of launch, a diagram of* Pioneer 10*'s home solar system, and two representations of its creators, standing in front of the parabolic antenna they used to communicate with their creation.* Images: NASA/Ames Research Center

WEIRD AND WONDERFUL: EUROPA KEEPS HER SECRETS

BY CHARLENE M. ANDERSON

Does she or doesn't she hide an ocean beneath that enigmatic face? That is the question planetary scientists—and oceanographers and biologists—are asking about Europa, the second large moon of Jupiter. As *Galileo* gets closer and closer in, some features the spacecraft sees suggest there may be liquid water close to the surface. Other details indicate it may be more mush than liquid. No one can yet say for certain what lies below, but there is hope—"hope" being a word not usually used in scientific contexts—that Europa does possess an ocean. And where there's liquid water—and organics and an energy source—there may be life.

On these pages you can see the latest images of Europa, taken on *Galileo*'s fourth orbit around Jupiter. The spacecraft had looked at this moon during its close encounters with Ganymede and Callisto, the outermost large satellites, but the best pictures then showed details only as small as 1.6 kilometers (1 mile) across. We now have pictures with details as small as 36 meters. And, as we see smaller and smaller details, Europa looks weirder and weirder.

From *Voyager* images taken 18 years ago, we knew that Europa was crisscrossed with strange linear features. *Galileo* revealed these to be ridges and grooves, some stretching across hemispheres. They have proven to be the dominant topographic form on Europa, and we are now seeing them down to the limit of resolution. The ridges probably form as viscous materials erupt through cracks in the icy surface. In some instances, the eruptions occur repeatedly, forming multitudes of parallel ridges and grooves within the lineaments. The best earthly analogy for this process would be mid-oceanic ridges, where magma from beneath the crust erupts again and again, adding to the margins of the tectonic plates that make up our planet's crust. But this comparison is not exact, for on Europa the crust is primarily water ice, not rock.

The energy to drive tectonism on Europa probably comes from tidal tugs from Jupiter and the other large moons in the Jovian system. This same mechanism drives the volcanoes of Io. If tidal forces are reshaping the face of Europa, the question remains whether these forces could provide enough energy to sustain a subsurface ocean and some form of life.

Within these detailed images, *Galileo* scientists find evidence that the energy source has reworked the moon's surface recently. Ridges are broken off, like freeway overpasses after an earthquake. Flows of thick, viscous ice have erupted from below, obliterating the linear features in some spots. Many regions have very few or no visible impact craters, indicating that they are young. The water must have flowed within the last few thousands or millions of years—the recent past, in geologic time. This is good news for those looking for a subsurface ocean.

But within these images the *Galileo* team also found a large circular feature that looks remarkably like an impact basin. If a liquid ocean exists beneath a thin ice crust, it would be hard to explain how a large impact basin could remain to scar the surface. Scientists can't be sure the feature is an impact basin—it also resembles the coronae seen in *Magellan* images of Venus. Coronae are circular features composed of concentric cracks that probably form when magma pushes up on a pliable surface but doesn't erupt through it. The jury is still out on this feature.

To make sense of Europa's face, scientists will have to see more of it. As Michael Carr of the United States Geological Survey said, "We've seen so little, it's hard to make grand interpretations." More data are coming. In late February, *Galileo* again flew by Europa and will soon return new images. With more information, scientists will be better able to unravel the moon's enigmas.

Ronald Greeley of Arizona State University, head of the Europa team on the *Galileo* project, indicates that, with regard to the ocean, they will be addressing three principal questions:

1. Is there any liquid water beneath the surface?
2. Is it confined to local hot spots?
3. Is it a global ocean?

Whether or not Europa does possess an ocean—and harbor the potential for life—it is one of the most fascinating worlds yet visited by humanity's exploring spacecraft. Recognizing this attraction, NASA has committed to extending the *Galileo* mission beyond its scheduled end in December 1997. After that date, controllers will direct the spacecraft to lower its orbit about Jupiter by making several close passes by Callisto. During the *Galileo* Extended Mission (GEM), the spacecraft will get into position to swing by Europa again and again, each time adding details to our picture of this weird world.

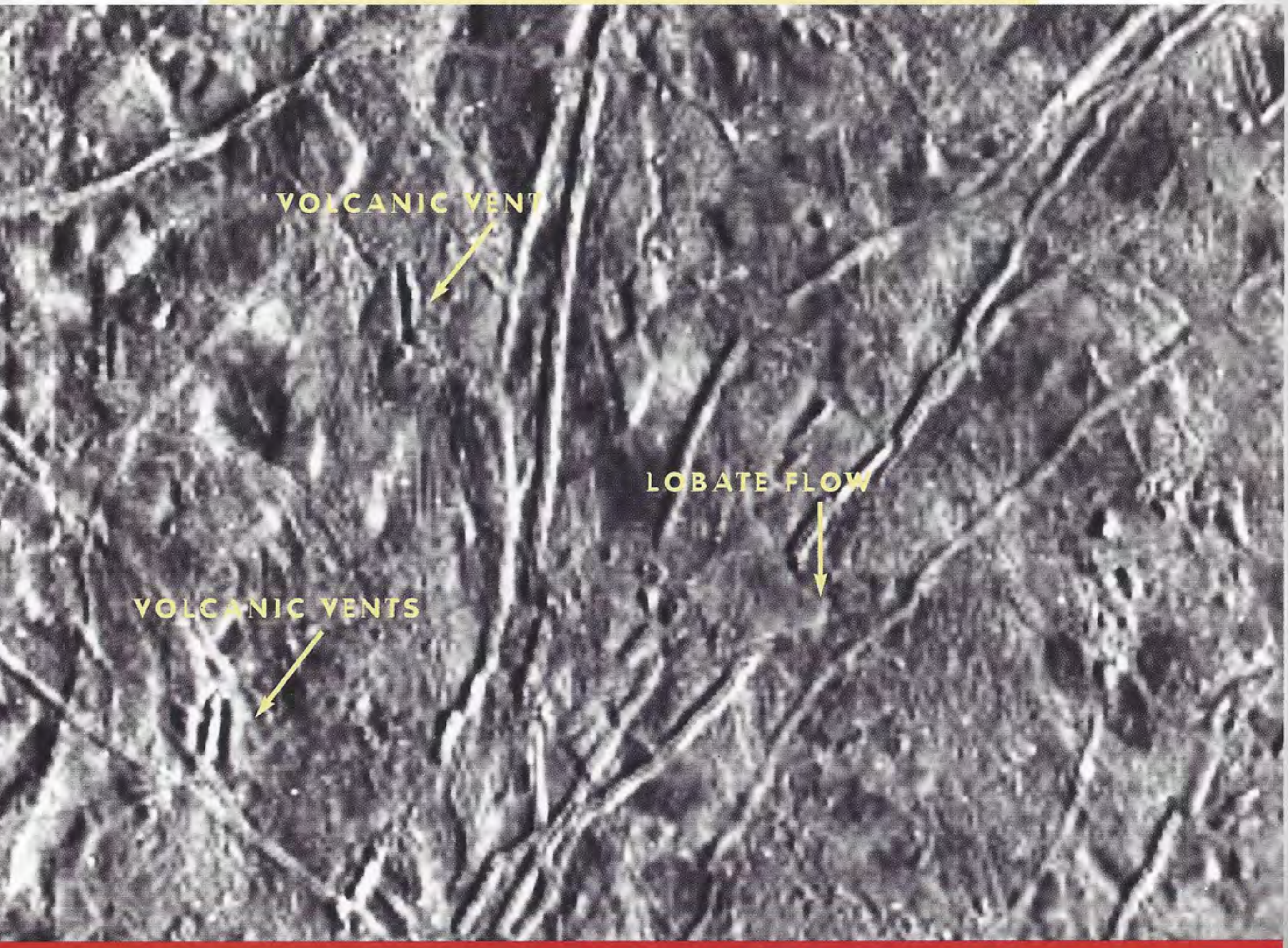
But even after GEM, it's possible that we won't know for certain if Europa has an ocean. We may need to land on this moon with geophysical instruments derived from equipment used by oceanographers on Earth. Last fall a group of ocean scientists gathered with their planetary counterparts at the San Juan Capistrano Research Institute in California to discuss strategies for exploring Europa. This little world is proving to be one of the most fascinating bodies in our solar system. So much is possible there, and there is so much left to explore . . .

Charlene M. Anderson is Director of Publications for the Planetary Society.

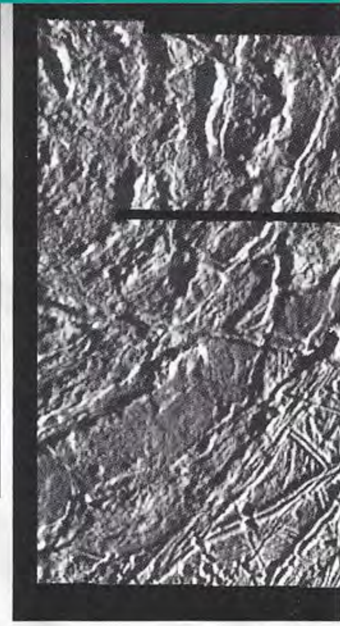
ICE VOLCANOES?

Are there ice volcanoes on Europa? In this image, scientists see features that look remarkably like terrestrial volcanic features—but, of course, on our planet melted rock, not water, creates the features. To the upper left of center, a dark feature very much resembles volcanic vents on Earth. In the lower left, too, a parallel pair of vents appears. In terrestrial examples, we often find vents of this kind associated with lobate flows of thick, slow-moving lava. Just below center in this image, a lobate flow has obliterated a ridge.

***Galileo** took this image from a distance of 62,000 kilometers (39,000 miles) from Europa, resolving details as small as 1.6 kilometers (1 mile) across. This image covers an area 126 by 393 kilometers (78 by 244 miles).* *Image: JPL/NASA*



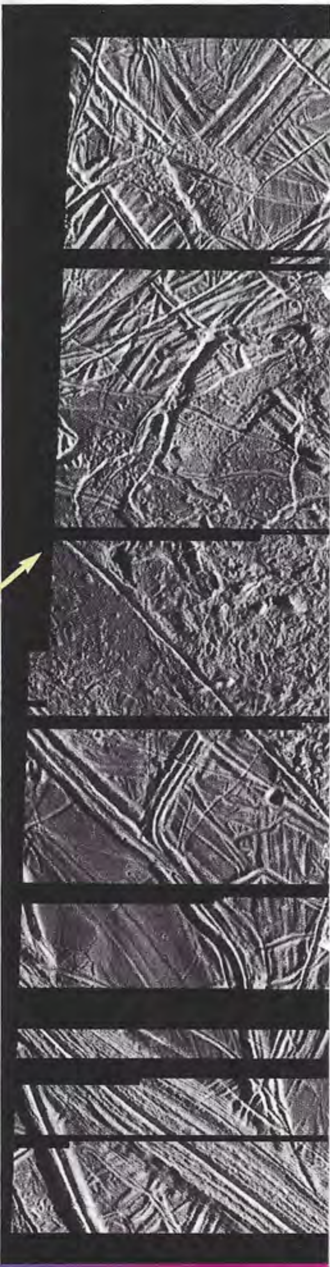
1. PUZZLING RINGS

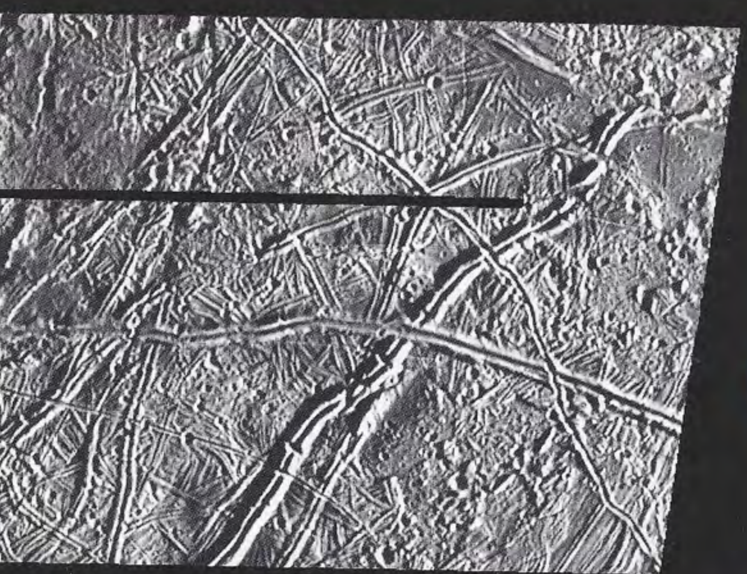


Is this an impact feature, the healed-over scar formed when some object punched through the thin icy crust to the mush beneath? Or is it a volcanic feature, formed when a plume of heated material pushed upward, leaving concentric rings on the disrupted crust? The answers to these questions could be critical to understanding the processes going on beneath Europa's puzzling surface. This feature, called a macula, is large, some 100 kilometers (60 miles) across. It would be difficult for a thin ice layer over an ocean to retain the concentric rings associated with impact basins, such as those on our Moon and Mercury. Scientists don't yet know enough about this feature to say exactly what it is. They can, however, say that it is relatively young, for this macula overlies the ridged terrain seen to the left and bottom right. This image covers an area 48 by 91 kilometers (30 by 57 miles), with details visible down to 240 meters across. It was taken from a distance of 11,933 kilometers (7415 miles). The black lines in these images are artifacts of processing.

3. RECENT SMOOTHING

Imagine now that you are riding on Galileo *as it closes in on Europa, swinging through its fourth orbit around Jupiter. From the distance of 62,000 kilometers (39,000 miles), you see the network of crisscrossing ridges that dominate the satellite's surface. Some ridges seem to have been broken or swept away by volcanic flows—and on this icy world, the volcanic flow is probably water. No obvious signs of impact craters catch your eye, so you conclude that this region is relatively young, and whatever processes created it have been active in the recent past. This view takes in an area 126 by 393 kilometers (78 by 244 miles), resolving details as small as 1.6 kilometers (1 mile) across. Your trajectory will soon bring you in for a closer, more detailed look at the region outlined in the upper left.*





2. DISRUPTED TERRAIN

This close-up of the region just to the right of the macula reveals several small craters, which may mark sites where debris fell after the impact that formed the ringed basin—if indeed the ringed basin is an impact feature. The ridges that dominate so much of Europa's surface are well represented here, looking much like freeway systems on Earth. Look particularly closely at the ridges just to the right of center, halfway toward the bottom. A dark zone appears to the right of one of the most prominent features, showing that something has recently wiped out some ridges. Underneath lies a disrupted ridge reminiscent of freeway overpasses broken in earthquakes.

The region here, covering an area 48 by 91 kilometers (30 by 57 miles), shows details as small as 240 meters across. This image was taken from a range of 11,850 kilometers (7400 miles).

4. HOW RIDGES BUILD UP

Now you're only 3400 kilometers (2100 miles) away, and you're struck by the complexity of Europa's surface. At the top left, you see how the parallel ridges have been broken and offset by movement in the surface layer. Lower down in the image is chaotic terrain, where the ridges have been destroyed. Below that you note some excellent examples of broken ridges. The landscape at the bottom of the image demonstrates how the parallel ridges form. Water, probably carrying silicate and sulfurous materials, erupts through long, linear cracks in the surface and oozes to either side. In some cases, the eruptions continue, with newer ridges pushing aside older ones. Eventually, long and broad lineaments cover large areas of the Europan surface. On Earth, scientists have watched similar processes forming the mid-oceanic ridges, where molten rock erupts to the surface, creating new crust. In this image, you can see details as small as 70 meters across covering an area 17 by 49 kilometers (11 by 30 miles).

5. CLOSEST VIEW YET

You've now zoomed in on the second panel from the top in the image at left. This is the most detailed view ever taken of Europa, revealing features as small as an earthly football field. In the center, you see where flows of icy material have obliterated the distinctive ridged terrain. To the right is knobby terrain of unknown origin. Small craters, from about 100 to 400 meters across, dot the frame, but whether they're scars of collisions with asteroids and comets or remnants of some internal Europan process, no one can say for certain. Everything about this moon is strange, intriguing, elusive—it must be seen again and again before we'll have a chance of understanding the inner workings of this mysterious world.

Galileo took this image when the spacecraft was only 3340 kilometers (2075 miles) from Europa's surface, showing an area 9.6 by 16 kilometers (6.0 by 10.0 miles). Images: JPL/NASA

SAGAN'S FIRE: A NEW CHALLENGE

BY BRUCE MURRAY AND LOUIS D. FRIEDMAN

A churning, violent, luminescent, and transcendently beautiful birthplace of stars, the Orion Nebula is only 1500 light years from Earth.

Image: C.R. O'Dell of Rice University; Hubble Space Telescope, NASA

The loss of Carl Sagan has filled all of us in the Planetary Society with deep sadness, but it is a sadness tempered by hope. We have come to see that the future among the planets we envisioned, with Carl's guidance, is within our grasp. Through his dedication and enthusiasm, the joy and wonder of exploring our neighboring worlds and searching for extraterrestrial life have been conveyed to millions who inhabit this world. Carl left a world ready and able to venture outward and to accept the great challenges posed by the universe around us.

This is Carl's legacy, and it is our task to build upon it.

So as a society of like-minded people, with a wide array of talents, how do we direct our energy as we continue Carl's work and expand his legacy? How do we galvanize individuals and institutions around the world into undertaking the great challenges? How do we grow our organization into a force capable of leading the endeavor of planetary exploration?

Consider all we have to work with:

- the continuing discoveries of planets around other stars;
- the discovery of possible ancient Martian life;
- two missions, *Mars Pathfinder* and *Global Surveyor*, on their way to explore the most Earth-like of planets;
- an ambitious and daring program to launch spacecraft to Mars at every opportunity;
- the *Galileo* spacecraft doggedly returning amazing data, despite a crippled antenna, from Jupiter and its moons;
- hints of a liquid water ocean beneath the frozen crust of Europa, one of Jupiter's largest moons;
- the Near-Earth Asteroid Rendezvous spacecraft preparing to fly by Mathilde on its way to its target, Eros;
- the *Cassini* mission preparing to explore Saturn, its rings, and its tantalizing moon, Titan; and
- active searches, by the Planetary Society and its allies, for radio signals from possible extraterrestrial civilizations.

This is the tinder to light again the fire for exploration in Earth's peoples. Better than anyone else, Carl knew how to spark our desire to see and understand the wonders of the universe. As an organization, it falls to us to continue his work.

As an organization, the Planetary Society must change and grow to meet this challenge. Indeed, having this challenge placed before us gives us both incentive and opportunity to improve and strengthen the Society. And so, we turn to our members for help and support.

We ask you to share your thoughts on what actions we should take in the next few months and years. How should we direct our energy? What roles should we play in advocating and, where possible, enabling planetary exploration and the search for life elsewhere in the universe? Are there activities we should drop to better focus our efforts? How do we encourage other people and organizations to join us?

Many other questions facing our organization may occur to you, and we would like to hear them and your ideas on how we should proceed. In this time of combined sorrow, hope, and opportunity, if we work together we can create a stronger, more effective force to achieve our shared goals. The solar system and the galaxy lie before us. We can help determine how humanity rises to the challenges they pose.

Bruce Murray, Professor of Planetary Science at California Institute of Technology, is Vice President of the Planetary Society. Louis D. Friedman is Executive Director.

World Watch

by Louis D. Friedman

Europe—The loss of *Mars '96* was a major blow to European planetary exploration as major participants France, Germany, Italy, and Finland lost about $200 million on their instruments and other commitments to the mission. Earlier in the year, the European Space Agency (ESA) had rejected plans for InterMarsNet, a cooperative mission with NASA to be launched in 2003 on an Ariane rocket. Now they have no Mars program.

In addition, ESA's science program faces a 15 percent budget cut over the next five years—in its already approved program. This is the first time ESA has had to absorb so large a cut.

The failure of the Ariane 5 launch of *Cluster*—four Earth-orbiting space science satellites—produced another financial blow to ESA. Funds to refly the mission are being sought.

But European space science also saw major successes in 1996. The Infrared Space Observatory and Solar and Heliospheric Observatory, two Earth-orbiting astronomy satellites, have been spectacular performers.

For this year, Europe has the *Huygens* atmospheric probe aboard the *Cassini* mission. *Rosetta*, a comet rendezvous mission, is scheduled for launch in 2003. The Europeans are considering several proposals for reflying their *Mars '96* instruments, though no particular spacecraft or launch opportunity has been identified.

With national agency budgets going down and ESA budget pressures continuing, there's impetus for major changes in European planetary programs, such as new cooperative ventures with the United States or smaller satellites and missions relying on innovative technology.

Japan—Japan plans to launch its first mission to land on another world—*Lunar A*—in August 1997. Whether this date can be met will depend on results of a trial launch of the M5 rocket. In 1998, the Japanese plan to launch *Planet B*, an aeronomy orbiter, to Mars (see the November/December 1996 *Planetary Report)*.

On the horizon are exciting plans for developing a near-Earth asteroid mission, *Muses C*, to launch in 2002 and return a sample to Earth in 2006. The target is asteroid Nereus, discovered by astronomer Eleanor Helin as part of the Society's asteroid research program and named by a Society member.

Japan's two space agencies, ISAS and NASDA, are getting together for the first time to conduct a lunar mission, tentatively scheduled for launch in 2002, known as *Selene*—the Selenological and Engineering Explorer.

Japan has produced a long-range space development plan that includes programs for a course of lunar exploration resulting in a robotic lunar base, perhaps by the year 2025.

Moscow—Russia is looking into *Mars '96* reflight alternatives, including smaller launches of different parts of the payload, international cooperative ventures, or simply moving on to other missions. The United States has asked Russia to endorse "Mars Together" and a plan to launch a Marsokhod rover in 2001 that would send data via the US *Mars Global Surveyor* orbiter.

Weakening support by the Russian government for science programs and their space agency has resulted in delays in the space station program—delays affecting the US program and cooperation between the two countries. But not all of the news is bad. Russia's 1997 budget, while allocating less to space exploration than requested, was 12 percent higher than in 1996.

Washington, DC—With the extraordinary interest in the possible Mars life discovery and the stellar performance of NASA science missions in the past year, there is hope that projected declines in funding will be averted. With the Near-Earth Asteroid Rendezvous, *Mars Pathfinder,* and *Mars Global Surveyor* on their way and *Galileo* and the Hubble Space Telescope returning exciting results practically every day, NASA's space science program enjoys a level of popularity and political support not seen since the 1970s.

Budget cuts are expected in fiscal year 1998. The pressures on NASA remain enormous. Program resiliency, the ability to respond to unexpected difficulties, gets squeezed when money is tight, and so does the agency's ability to respond to new initiatives, such as a Mars sample return, the *Pluto Express,* and follow-up investigations of Europa and the outer-planet satellites.

Planetary Society members will soon receive special mailings and appeals to advocate government support for space exploration missions in the US and in other nations.

Louis D. Friedman is Executive Director of the Planetary Society.

Basics of Spaceflight:

End-to-End Data Flow—The Downlink Part

by Dave Doody

This installment, together with the preceding one on uplink, offers a large-scale view of how uplink and downlink work together as a system, bringing measurements of distant objects in the solar system to our front doors and to our home computers.

Uplink refers to radio signals sent to a spacecraft; *downlink* is a transmission from the spacecraft to Earth. Once an uplink has been sent and its commands carried out by the spacecraft, two kinds of results come back on the downlink. One is telemetry, meaning onboard measurements that have been converted to radio signals. The other includes tracking and radio science data.

The downlink contains both engineering and science information. Engineering telemetry, for example, includes the temperature of nearly every spacecraft component as well as voltages, currents, pressures, and other measurements. Engineers rely on these measurements in their operation of the spacecraft. Tracking and navigation data (described more fully in the July/August 1995 *Planetary Report)* fall under the engineering heading, too.

Under the science heading we include data from the science instruments and imaging equipment (which are telemetry) and the radio science data. In a radio-science experiment, the downlink may yield atmospheric-sensing results or provide tracking data to determine the mass of a planet or moon.

Transmission of science data, whether telemetry or radio science, enjoys the highest priority in the end-to-end system. Engineering data have a repetitive nature: if some information is lost, it's usually no big deal, because the same measurements will probably recur in a short time. Science is the diamond amid rhinestones. Its receipt is the purpose of flying spacecraft in the first place.

How We Listen

A broad definition of *downlink* encompasses receiving, deciphering, storing, distributing, displaying, archiving, and publishing the data. The result of the end-to-end system is that science data reach the worldwide public, including the people who fund missions with their taxes.

The diagram on the next page depicts a typical Jet Propulsion Laboratory (JPL) project, such as *Galileo, Mars Global Surveyor*, or the soon-to-launch *Cassini* mission to Saturn. Many of the components pictured are shared by several projects. Going from left to right, the diagram shows that the spacecraft's scientific instruments collect images, spectra, and other data, which then go to a storage device aboard the spacecraft, such as a tape recorder. That device, under the control of a computer, plays back the information when Earth is listening. Hardly a bit of precious science data is ever lost permanently. If information gets garbled on the way down—because of a rainstorm, for example, over the receiving station of the Deep Space Network (DSN)—controllers can command the spacecraft to replay the data when Earth rotates a drier DSN station into view.

The downlink radio signal is pretty weak, having traveled a long distance. It takes large-aperture radio telescopes to collect and concentrate the signal. The antenna has to be pointed in exactly the right direction to locate the spacecraft in the sky. Once the downlink signal has been funneled in, we boost it in the antenna with a low-noise amplifier kept at very low temperature to minimize electronic noise.

From the low-noise amplifier, the signal goes to a radio receiver that automatically tunes in the right signal. Once the receiver has locked onto the downlink, the signal goes to a telemetry processor, which converts the signal to binary digits (bits), all ones and zeros, the same digital information originally generated by the spacecraft instruments. The DSN transmits these telemetry bits to JPL via the Ground Communications Facility (GCF), which despite its name relies on satellites for communications. In addition to telemetry, the DSN captures tracking data and radio science data. In the diagram, we see data coming in to JPL, where preliminary processing removes GCF transport information and decommutates the channels.

Decommutates the channels, he said! Remember, a spacecraft sends lots of engineering and science measurements. *Decommutating* means determining the kind of data being received. *Channels* are categories of data. For example, instead of always referring laboriously to "the temperature data on reaction wheel motor number one," we just call it something like "Channel E-1654." E-channels are for engineering data, and S-channels are for science data.

TDS Has Results Right Now

The telemetry, now "channelized" to identify its contents, is typically stored within a Telemetry Delivery System (TDS) for the entire life of the mission. TDS distributes telemetry to people who should receive it right away: the real-time flight controller who is looking out for surprises,

End-to-End Downlink Flow

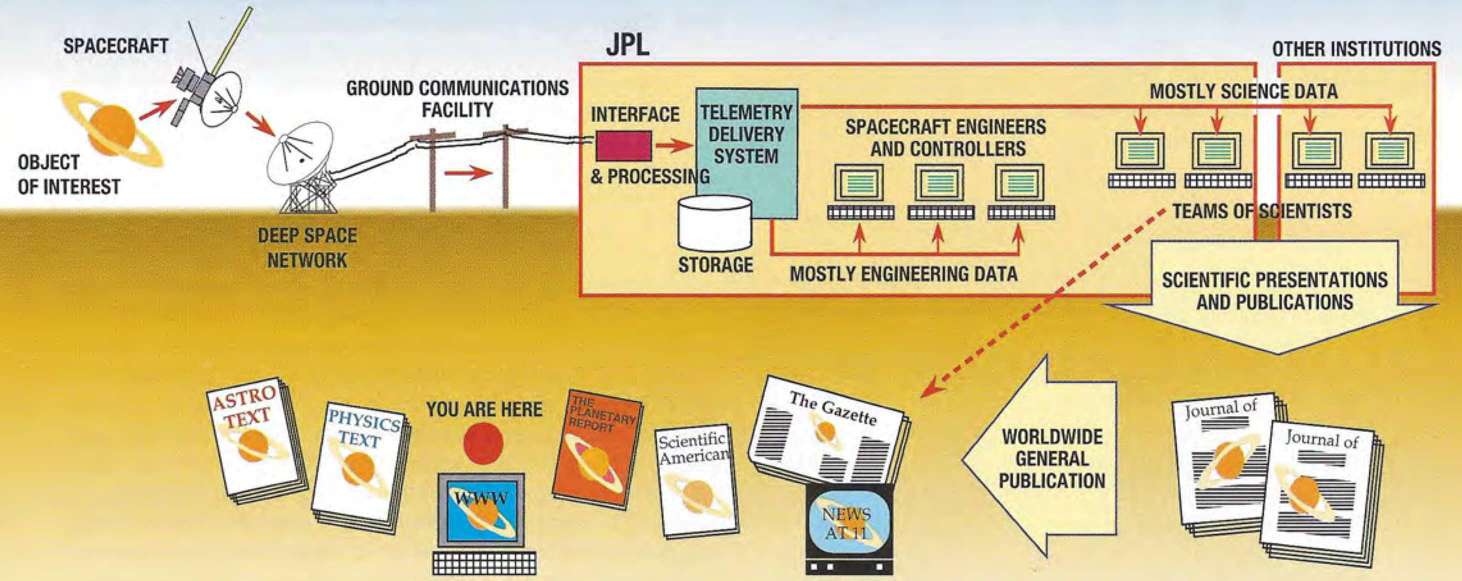


CHART BY DAVE DOODY; MODIFIED BY B. S. SMITH

the engineer who needs to watch a propellant tank temperature, or the scientist waiting for findings from a particular instrument.

TDS users can custom-order the telemetry they need. For example, a science team analyzing data from a photopolarimeter experiment might need to look at radio-receiver performance to be sure of their results. Another supplementary data set includes spacecraft and planetary positions and instrument pointing. With this information, we can determine exactly where in space the data were gathered from and thus where they fit in relation to other collected data.

Once a team of scientists has correlated and analyzed the telemetry and supplementary data, they will want to publish their results in a scientific journal, but even before these scholarly articles appear, the public gets a look! NASA policy calls for immediate publication of images returned from planetary encounters (represented by the dashed arrow in the diagram). These "first-look" images are preliminary and usually lack the high resolution scientists need for extensive analysis and reporting.

Serving a World of Data Consumers

Data from planetary missions are made available worldwide through Regional Planetary Imaging Data Facilities, operated by NASA at more than a dozen sites around the United States and overseas. Each maintains a complete photographic library of images from lunar and planetary missions. These sites are open to the public by appointment for browsing and ordering materials for purchase.

Researchers funded by NASA obtain planetary imaging data via the Planetary Data System, which consists of a central on-line catalog and data retrieval nodes at various research facilities.

Classroom educators can obtain videocassettes and a wide variety of other materials on NASA's flight projects through Educator Resource Centers (which until just recently were called Teacher Resource Centers).

Flight projects are making increasing use of the World Wide Web to disseminate preliminary images as well as full scientific results: this is a "high leverage" avenue, meaning that a very large number of people can be served with a minimum investment of resources. Be sure not to miss *Galileo* and other Web sites accessible from www.jpl.nasa.gov.

If you don't normally have access to the Web, come to Planetfest '97 in Pasadena this July and hook in via the high-speed Internet browsing computers that will be available.

In the next installment, we'll take a good look at the Deep Space Network. Without the incredible capabilities of the DSN it would be impossible to accomplish any planetary exploration at all.

Dave Doody is a member of the Jet Propulsion Laboratory's Advanced Mission Operations Section and is currently working on the Cassini *mission to Saturn.*

If you have access to the World Wide Web (via a Web browser like Netscape or Mosaic), be sure to look in on JPL's *Basics of Space Flight* manual, on-line at http://www.jpl.nasa.gov/basics/.

News and Reviews

by Clark R. Chapman

Europa, Jupiter's second moon, has been much in the news of late. A recent *Galileo* image of Europa graced the cover of *Discover*'s January "Year in Science" issue. NASA has given the go-ahead for a Europa-intensive continuation of the *Galileo* mission. And there has been much public speculation about a possible ocean, even life, on this baffling body.

The classic textbook *Astronomy* by Henry Norris Russell, Raymond Smith Dugan, and John Quincy Stewart, published 70 years ago, reports that the diameter of Europa is 3150 kilometers (or 1960 miles, a bit smaller than the Moon), that its surface is very bright, that it keeps one face to Jupiter, and that it is made mostly of rock—different from the much icier compositions of Ganymede and Callisto. The only thing learned from the next 50 years of telescopic observations was that Europa's bright surface is, indeed, due to water ice. Theoreticians then speculated that there might be a shallow mantle (or "ocean") of liquid water beneath the ice, but the picture of Europa as an essentially rocky body remained unchanged.

Voyager 2's flyby in 1979 revealed a perplexing network of lines on Europa's nearly craterless surface that resembled Percival Lowell's fanciful network of Martian canals. But the spacecraft was too far away to tell us anything more about Europa's geology or its interior. After allowance for *Voyager*'s margin of measurement error, Europa's size remained exactly as given by Russell, Dugan, and Stewart. In the 1980s, several researchers debated whether or not there was a subterranean ocean on Europa. Last December 19, as *Galileo* flew to within 700 kilometers (400 miles) of its surface, Europa remained an enigma.

Slowly, but surely, during the next three years, Europa's veil of mystery will be lifted under *Galileo*'s intense gaze, and we will finally learn whether to expect even richer wonders beneath its surface.

Jack Frost's Artistry

At a January 17 press conference at NASA Headquarters, *Galileo* researchers released close-ups of a landscape like no other in the solar system. On a scale of meters to kilometers, nature has etched a geometric pattern of icy features as unexpectedly intricate as Jack Frost's icy patterns on our window panes. The freeway-like ridges of ice sometimes intertwine as though they were created by a cosmic basketweaver.

Craters are scarce on Europa's surface, raising the possibility that active water-ice volcanism may still be occurring on its surface, with eruptions of water from below keeping the icy surface fresh and bright, despite the black rain of cosmic debris. Indeed, Arizona State University researchers Ron Greeley and Rob Sullivan have reported tantalizing evidence of ice volcanoes and smooth glacier-like flows on the otherwise tortured surface of Europa, keeping alive the idea of a subsurface ocean.

But it is notoriously difficult to prove what lies within a body that can only be observed from the outside. If you didn't know already, would you ever guess—from the external appearance of a banana peel—what the fruit inside is like? Just how thick is the ice on Europa? Lacking instrument data that would give a definitive answer, Brown University geologist Jim Head draws an evocative analogy: if he saw a frozen-over New England pond that looked like Europa, he wouldn't dare skate on it! What we really need is a network of seismometers on Europa to probe its interior. For now we at least have *Galileo*, whose close flybys will soon take us beyond the standard guess that Europa is basically a ball of rock with only a thin water-ice crust. With gravity data already sent home, and more to come, *Galileo* may soon treat us to further surprises.

Extrasolar Europas?

Let your imagination take wing, and consider those recently discovered Jupiter-like planets in Earth-like orbits around other stars. Until now, the search for extraterrestrial life has concentrated on the concept of Earth-like planets around the billions of stars that might have their own solar systems. As Russell, Dugan, and Stewart wrote 70 years ago, "Here and there, at least, among these there should be planets large enough to retain an atmosphere, with water upon their surfaces, and at such distances from the stars about which they revolve that their surfaces are maintained at a genial temperature."

Now Darren Williams, James Kasting, and Richard Wade of Pennsylvania State University, writing in *Nature* for 16 January, ask us to imagine what Europa would be like if its parent planet were as close to the Sun as the Jovian companions of 16 Cygni B and 47 Ursae Majoris. In a comment on their article in the same issue of *Nature*, Chris Chyba of the University of Arizona pays tribute to Carl Sagan's pioneering work in this field. With a Saganesque flair, he questions the chauvinism of the criterion that habitability necessarily involves surface liquid water.

Who can say how narrow, or broad, is the range of conditions sufficient for the origin and sustenance of life? Practicality dictates that we explore the question one step at a time. Mars and Europa appear to be next in line.

Clark R. Chapman, who took Carl Sagan's course on "The Planets" in 1965, is researching Europa as a member of the Galileo *Imaging Team.*

Society News

Planetfest '97 Takes Off

Plans are well underway for Planetfest '97, taking place July 3-6 at the Pasadena Convention Center in Pasadena, California. An enormous variety of exhibits and displays will fill the convention hall, including the Mission Status Board and Video Wall, a state-of-the-art projection system that will follow the historic July 4 *Mars Pathfinder* landing as it happens. The Hall of Technology will feature exhibits of technological innovations in space science and exploration, and A Child's Universe will showcase hands-on fun, including the Society's popular Red Rover, Red Rover Project. Movies, art, and books, plus exciting presentations, discussions, and debates by some of the world's leading scientists and thinkers will all be part of the four-day space celebration. For information contact me at Society headquarters or by e-mail: tps.cj@mars.planetary.org.
—Cindy Jalife, Planetfest Coordinator

META II Restarts SETI

The Mega-Channel Extraterrestrial Assay (META) II project, which has been searching for signs of extraterrestrial intelligence (SETI) from Earth's southern hemisphere, is once again in operation. The system was shut down in November 1995 due to a failure in its old Wicat computer.

The META II system was installed on one of the two 30-meter antennas at the Argentine Institute for Radioastronomy, located 50 kilometers (30 miles) south of Buenos Aires. Observations began on October 12, 1990. With funding from the National Research Council of Argentina, observations of the southern sky (at declinations between -10 and -90 degrees) have been conducted on 80 nearby stars that may have solar systems.

Southern-sky observations began again with the repaired old system on December 26, 1996, with installation of the new system planned for the end of 1997. "The incredible efforts of our US colleagues, as well as the entire Planetary Society staff, have made this possible," says Guillermo A. Lemarchand, a researcher at the Argentine Institute for Radioastronomy and editor of the Planetary Society's *Bioastronomy News*. "We would particularly like to thank all Planetary Society members whose generosity allowed us to continue with the project."
—Bill McGovern, Production Editor

Crater Chasing in Belize

The Planetary Society is organizing another expedition in our Cretaceous-Tertiary (K/T) series of searches for evidence of the impact 65 million years ago that led to the extinction of the dinosaurs. Slated for January 1998, the expedition to central and southern Belize will attempt to determine the extent of ejecta deposits from the Chicxulub crater and their stratigraphic relationships. The expedition is limited to 12 participants and will cost about $2300 per person, excluding airfare. For information, contact me at Society headquarters or by e-mail: tps.lc@mars.planetary.org.
—Lu Coffing, Financial Manager

Test Balloon Explodes

A prototype Mars balloon constructed of a new nylon material failed on its first test flight last November at Utah State University. The balloon exploded on the ground during inflation, which fortunately prevented the loss of the gondola and payload and allowed the university's technical team to examine the balloon carefully to determine the exact cause of the failure.

A manufacturing defect was discovered in the upper seam of the balloon, and the balloon manufacturer agreed to provide another balloon to be tested in early 1997. The Planetary Society and NASA/Ames cosponsored the test. For a play-by-play of the test, check the Society's Web site: http://planetary.org/tps/.
—Louis D. Friedman,
Executive Director

View the '98 Eclipse

The Planetary Society is offering two tours to view the total solar eclipse that will occur February 26, 1998. A Caribbean cruise and a land tour to Aruba, which includes an optional visit to the Ariane launch site in French Guiana, will provide rare viewing and photographing opportunities of the three-minute-forty-five-second event. Space is limited and will fill up quickly. For more information and a free brochure, contact me at Society headquarters or by e-mail: tps.sl@mars.planetary.org.
—Susan Lendroth,
Manager of Events and Communication

We Need Your Help

Sign up now to take part in the Planetary Society's Planetfest '97, July 3-6, 1997, at the Pasadena Convention Center in Pasadena, California. We need volunteers to hand out information, take tickets, check badges, operate slide projectors, navigate the World Wide Web, build water rockets, tally sales orders, and assist in many other areas. For information, contact Volunteer Coordinator Carlos Populus at Society headquarters or by e-mail: tps.cp@mars.planetary.org.
—SL

More News

The Mars Underground News:
Life after meteorite ALH84001 and new strategies for continued Mars exploration.
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The Bioastronomy News:
A tribute to Carl Sagan and his impact on bioastronomy.

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Questions and Answers

When we finally do get to the point where we have explored the Moon in detail, what is the likelihood that we will find Earth rocks there just as we find Mars rocks on Earth?
—Gary Gilbert,
Corona, Arizona

Finding an Earth rock on the Moon is possible but very unlikely, even for an expert looking for such a rock. Mars and Moon rocks are very rare on Earth. There are about 4000 known meteorites, of which only a dozen are believed to have come from Mars or the Moon. Most people, including geologists and meteoriticists, walk the Earth their entire lives without finding a single meteorite. Most of the meteoriticists who "discover" new meteorites depend on someone from the general public to bring in a strange rock they have encountered. About one in 500 such rocks turns out to be a real meteorite.

Meteorites are collected in the highest abundances in places where a solid stone is very unusual. Early in this century Harvey Nininger collected many meteorites from farmers in the plains states of Kansas and Nebraska, where any stone in the soil was an anomaly. In more recent years, expeditions to Antarctica have turned up meteorites in "blue ice regions," where the ice flow is forced to the surface and the wind then erodes away that ice—exposing any rocks embedded within. (See the January/February 1997 issue of *The Planetary Report)*. Again, a stone of any sort is rare on the ice and so has a high probability of being a meteorite.

Unfortunately, the Moon probably does not have any such stone-free regions, so meteorite hunters there would have to examine literally millions of rocks before they had a reasonable probability of turning up a meteorite. Nevertheless, *one* such meteorite fragment was found by Hap McSween of the University of Tennessee while he was examining a lunar soil sample brought back by the *Apollo* astronauts. The millimeter-sized fragment of carbonaceous chondrite was found on the rim of a small crater and is probably a remnant of the meteorite that made the crater. However, given the care with which the *Apollo* samples were examined, the "one in a million" estimate is probably not far out of line.

Another problem with finding meteorites on the Moon is the lack of an atmosphere. Meteorites "hard land" on the Moon's surface and so are mostly melted and vaporized (with the exception of a few small fragments like the one mentioned above). Earth's atmosphere decelerates incoming meteoroids with diameters up to a few tens of meters and drops the slowed stones relatively gently to the surface, where they can be collected more or less intact. On the Moon only a small fraction of the back surface of a "hard landed" meteorite spalls (breaks or chips) off during the impact and is thrown out of the crater, along with a much larger volume of ejecta from the Moon's surface.

Perhaps the best strategy for finding Earth rocks on the Moon would be to look at the ejecta deposits of small craters, searching for fragments of the impacting meteoroid. If the occurrence of Earth rocks on the Moon is similar to that of Mars rocks on Earth, you would have to examine about 300 craters (and find identifiable fragments of each projectile!) before there was a reasonable chance of finding one made by an Earth rock.

I doubt that any funding agency, such as NASA or the National Science Foundation, would back such a high-risk project. You will probably not hear about Earth rocks found on the Moon very soon, unless someone comes up with a clever technique of picking them out of the vast sea of broken rocks that litter the Moon's entire surface.
—H. J. MELOSH,
University of Arizona

Why does the heliopause also define the outermost extent of the Sun's magnetic field? The solar wind doesn't have anything to do with creating the magnetic field, does it?
—James W. Jones,
Colonial Heights, Virginia

No spacecraft has observed the heliopause region yet. However, current theory suggests that the outflowing solar wind and the magnetic field embedded in it should run into and pile up against the interstellar plasma (plus its embedded magnetic field). The heliopause is the boundary that separates these two plasmas (ionized gases whose free electrons carry electrical currents coupled to the magnetic field). As new solar-wind plasma continually arrives at the heliopause, it turns and flows parallel to the motion of the interstellar plasma (relative to the solar system). In this respect our solar system should resemble a gigantic comet, complete with a tail hundreds of astronomical units long.

The reason that the Sun's magnetic field extends measurably all the way to the heliopause is that it is dragged out there by the solar wind. (Describing the solar wind as "dragging" the Sun's magnetic field is only a conceptual crutch, but quantitative physics produces the same result.) By dragging the Sun's magnetic field lines out to the heliopause, the solar wind causes the solar field strength there to be greater than it would be otherwise. This increased magnetic field energy at the heliopause comes at the expense of a small fraction of the solar wind's energy of motion.

With luck and longevity, *Voyagers 1* and *2* should encounter the heliopause within a decade or so and radio back their observations of this most rarefied of high-vacuum phenomena. At that point the spacecraft will leave behind the last vestiges of the solar system. Both will continue to report on the interstellar plasma and magnetic field until onboard power runs out about the year 2020.
—FLOYD HERBERT and ALEX DESSLER,
University of Arizona

If there is now another civilization on a planet 50 light years away, with equipment similar to the Billion-channel Extraterrestrial Assay (Project BETA), would it be able to detect the radio transmissions broadcast from Earth in 1946?
—Sam Walker,
Harrogate, Yorkshire, England

In a word, no. Project BETA (like just about every other search) isn't looking for domestic broadcasting activities of alien civilizations—as nice as that would be—simply because it would require resources far beyond anything we could muster. This was recognized way back in the early 1970s, when the Project Cyclops study concluded that Earth's radio "leakage" (that's what they called it, honest!) would be detectable out to 50 light years (exactly your number) by an alien civilization if it used an antenna 5 kilometers (about 3 miles) in diameter. Such an antenna is extravagantly beyond the resources of the Planetary Society, or just about any other entity on Earth right now. On the other hand, if we were to transmit, with contemporary technology, an intentional beacon signal, optimized for the job of establishing communication, Earth could be seen, with relative ease, by a similar civilization out to thousands of light years.

I think your question has another layer—something like "why should we be looking for signals unlike those we are now transmitting?" A good and provocative question. Given that we are pretty much guaranteed to be the least advanced civilization trying to communicate (go back a hundred years and we've got no radio telescopes, computers, or electronics), it's only reasonable to assume that the more advanced civilization (i.e., Them) will use effective and proven beacon signals to bring new members into the galactic Internet. So the question should perhaps be, "Can BETA detect a beacon of the sort an advanced civilization, or galactic consortium, might well be sending?" We don't know for sure, but we certainly hope so.
—PAUL HOROWITZ,
Harvard University

Factinos

Two new members of our solar system—a near-Earth asteroid and a distant comet making its only appearance—have been detected by scientists from the Jet Propulsion Laboratory. The discoveries, reported on January 10, 1997 by Eleanor Helin and her team, were made with the Near-Earth Asteroid Tracking (NEAT) system at Mount Haleakala on Maui, Hawaii.

"This asteroid is a member of a rare class of asteroids, called Atens, which stay within Earth's orbit most of their lifetimes," said Helin of the new body, dubbed 1997 AC11. The asteroid is a faint object that measures about 183 meters in diameter.

The team also discovered a new comet, designated Comet 1997 A1. "This comet has traveled a long distance, originating in the Oort Cloud, far beyond Pluto's orbit," Helin said. "It has a parabolic orbit, which means it will travel through our solar system once and probably never be seen again. Parabolic comets do not present their calling cards before arriving in the inner solar system. They appear without warning."
—from the Harvard Smithsonian Center for Astrophysics

Galileo captured an image (below) of Jupiter's ring system on November 9, 1996. This view shows the west ansa ("loop" or "handle") of Jupiter's main ring with details as small across as 24 kilometers (15 miles). Internal structure is clearly visible here—something *Voyager* images merely hinted at. Variations in the ring's brightness are caused by the perturbations of small satellites.

Adrastea and Metis (two small satellites not visible in this image) orbit through the outer portion of the ring; scientists will determine their locations relative to these features after further analysis.
—from JPL/NASA

This Galileo *picture of Jupiter's ring system reveals details much finer than were possible in* Voyager*'s ring images.*

Image: JPL/NASA

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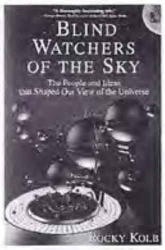

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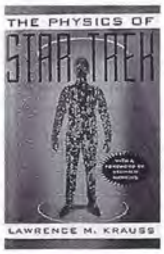

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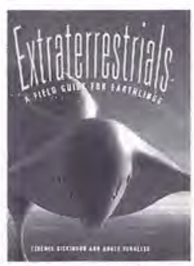

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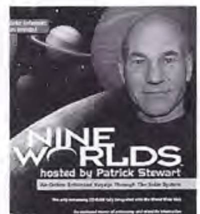

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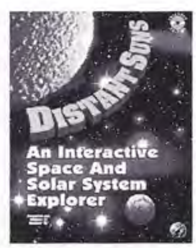

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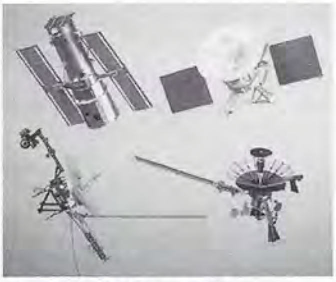

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Lava Flows by Perli Pelzig was inspired by the sight of molten lava running into the ocean. Spacecraft images of Mars tell us that in the ancient past lava and liquid water flowed over its surface as well. Our sister planet Venus has also seen its share of volcanic activity. And now *Galileo*'s recent images of Europa offer hints that eruptions may be taking place in an ocean under that moon's icy crust. This painting, finished in 1953, is part of a series of works entitled "My Universe."

Perli Pelzig was born in Poland in 1917 but has lived most of his life in Germany, Israel, and the United States. In addition to painting, he has produced works in various media from sculpture to stained glass for universities, synagogues, churches, and other public buildings.

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