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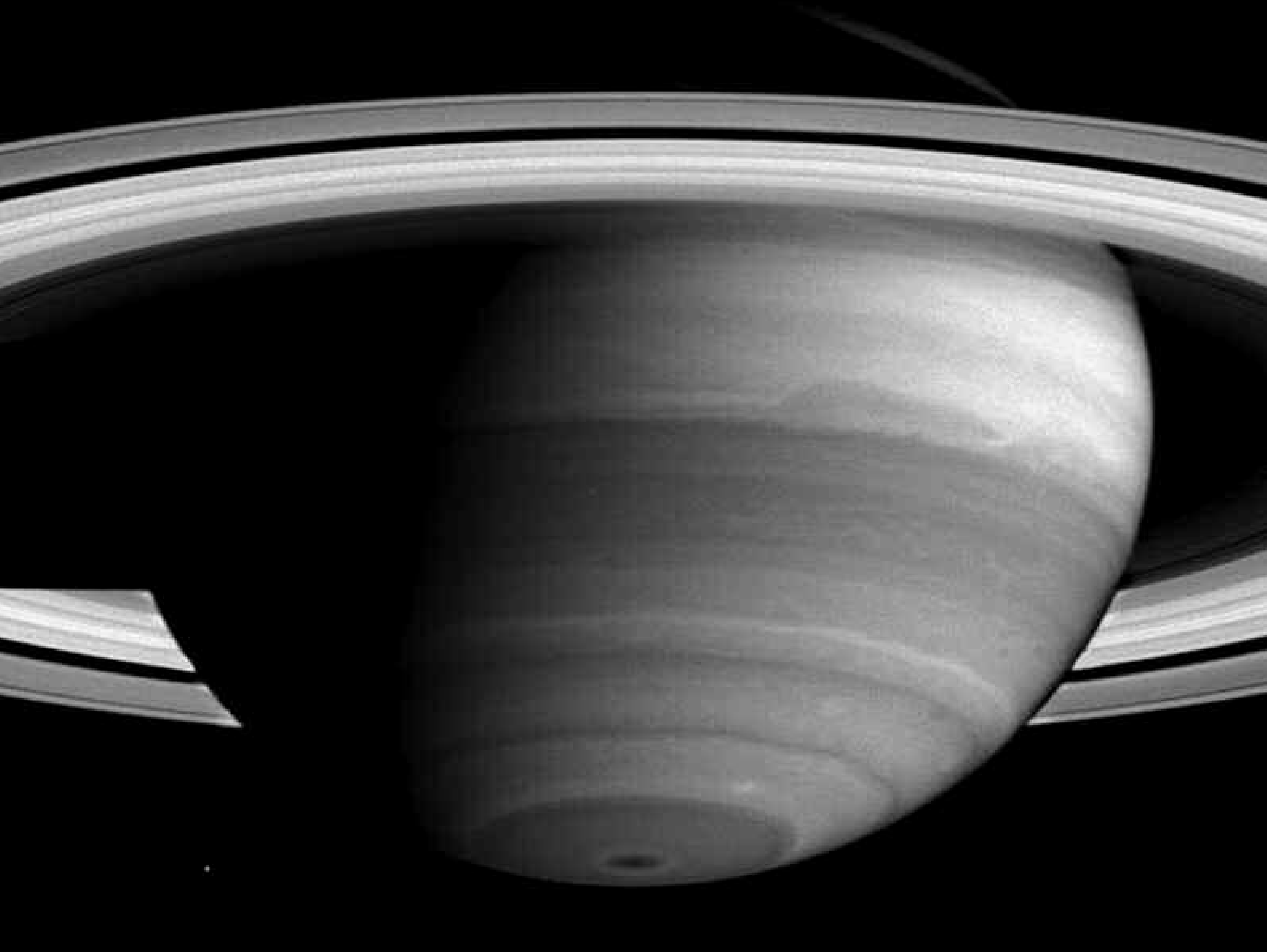

Saturn—Up Close

A PUBLICATION OF THE PLANETARY SOCIETY

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From The Editor

Next year, The Planetary Society will celebrate its 25th anniversary—a quarter-century of helping to make space exploration happen. The first issue of *The Planetary Report* featured *Voyager 1*'s encounter with Saturn, and in the time since then, we've covered missions from Venus to Neptune and reported on plans to take us from Mercury to the stars.

Not all those years were rich in discoveries. From 1977 to 1989, NASA launched no new spacecraft, while Europe, the Soviet Union, and Japan explored the solar system only as far out as Venus. Sometimes we had to be creative in filling these pages.

But today, we're swamped with new discoveries as *Spirit* and *Opportunity* investigate plains and craters of the Red Planet while *Mars Express* explores from orbit, along with *Mars Global Surveyor* and *Mars Odyssey*.

Cassini has reached Saturn and is now exploring that ringed world. In January, *Huygens* penetrates Titan's atmosphere. *Smart-1* is on its way to the Moon, and *Genesis* is on its way home with samples of the solar wind.

This may well be the richest year since the Society's founding for sheer volume of discoveries—and now the task is to fit it all into only 24 pages. There's more than enough to keep us busy for the next 25 years.

—*Charlene M. Anderson*

On the Cover:

Cassini-Huygens, too close to image a full view of Saturn, took this picture on April 16, 2004 from a distance of 38.5 million kilometers (nearly 24 million miles). Contrast has been enhanced to make features in the atmosphere easier to see. The bright dot to the left of the south pole is Saturn's moon Mimas.

Image: JPL/NASA/Space Science Institute

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Members' Dialogue

Inspirational Work

I would like to say to Charley Kohlhase that I really enjoyed your story on the *Cassini-Huygens* mission in *The Planetary Report*. (See "Return to Saturn's Realm" in the March/April 2004 issue.) I'd like to offer my humble congratulations on your past achievements and those of all your work teams. You are the ones who really make it happen!

Your collective work is truly an inspiration for thousands of anonymous folks like me who just love space exploration and the efforts of humankind to try to explore the cosmos and to understand our place in it. Thank you for keeping our spirits lifted.

And to *The Planetary Report*'s editorial team, you just keep getting better! I'm an avid science reader, but I must confess that you make the only magazine that I eagerly read from cover to cover, including the ads and even the Balance Sheet!

Truly awesome!
—RICARDO NUÑO SILVA,
Almada, Portugal

Notes From Cyberspace

Here's a sampling of what our members are saying about *planetary.org*.

On our Mars Exploration Rover coverage:

Very well done. The major news sources are so watered down. I like to see as much detail as you can give us on what's going on up there, what they're finding out with these instruments. Don't spare the details and charts.

I love the Planetary Radio too. Keep up the good work.
—MARK GESSNER,
Austin, Texas

Your coverage of the *Spirit* and *Opportunity* rovers is far better than any other source; even better than NASA (whose web developers apparently do not like doing updates on the weekend!).

I am proud to be a member of The Planetary Society (I joined during the first year!) and that, in a small way, I and other members helped make possible the fascinating exploration now under way. Keep up the great work!
—R. PATTERSON,
New Town, North Dakota

I have been a member for a few years now and have kept up on the news through The Planetary Society's magazine. However, with the Mars rovers on the surface, I checked out the website. Wow, you guys have the best pictures, the best detailed reports from NASA and the Jet Propulsion Laboratory, and excellent coverage!

I log in every day now.
—ERIC J. SMITH,
Goleta, California

Best images I have seen so far on the web. Brilliant! Keep it up.
—B. P. HUGHES,
London, England

On Wild About Mars:

I had the privilege to join the other Planetary Society members on January 3rd for that heart-stopping 10 minutes while we awaited a signal that the rover had safely landed on Mars. It gave me a small idea of how you all must feel actually being involved in such a project.

I'm so happy that our president is now making it a priority for our country that we move ahead in exploring space. It is the right thing to do, because all of our future is about space. Keep up the fantastic work and we'll all keep backing you up.
—DOUG SHATTUCK,
Encinitas, California

On the DVDs aboard the rovers:

I signed myself up, along with several family members and friends, back in 2001. It's been a really big talking point ever since! They have their certificates on their walls, framed and in places of honor. It's so much more interesting than talking about the weather or what's on TV.

The DVDs have really made people feel that they are a part of this historic event and have really opened up their eyes to the wonders of the universe. I would like to thank you sincerely for this. It's just fantastic!
—KAREN MARSHALL,
Lancashire, England

Please send your letters to
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We Make It Happen!

by Bruce Betts

Look up! Are you watching the skies, looking for potentially dangerous space rocks headed for Earth? Are you listening for signals from distant civilizations? As a Planetary Society member, you can say "yes!" Through your membership, you are supporting some of the most dedicated sky-watchers who search and track near-Earth asteroids and comets, and you're also supporting SETI@home, linking nearly 5 million people with the Search for Extraterrestrial Intelligence (SETI).

More Eyes Watching the Skies

In 1997, the Society began the Shoemaker NEO Grant program in honor of planetary geologist Eugene Shoemaker. The Shoemaker NEO Grant program is intended to increase the rate of discovery of NEOs and the extent of follow-up studies by providing dedicated amateurs, observers in developing countries, and professional astronomers with seed funding to expand or begin programs.

Since founding the Shoemaker NEO Grant program, the Society has awarded grants to 17 recipients in countries spanning the globe. We're about ready to announce the next round of Shoemaker NEO Grants, but before we do, I'd like to update you on what some of our past awardees have been doing.

After his Shoemaker NEO Grant covered the costs for 60-centimeter (24-inch) robotic telescope motors and drive electronics, Herman Mikuz of Slovenia has made 90 new main belt designations, 2 NEO discoveries in 2003, follow-up observations for 22 newly discovered NEOs, follow-up observations for 8 newly discovered comets, and confirmation observations for 4 newly discovered comets.

David Dixon in New Mexico used his 2000 Shoemaker NEO Grant to purchase a charge coupled device (CCD) camera to obtain more than 1,100 NEO position measurements.

In Arizona, Roy Tucker ran the world's eighth most productive asteroid astrometry station in 2003, thanks to his Shoemaker NEO Grant. He made 50,779 asteroid astrometric observations, including both known NEOs and discoveries of 4 NEOs and 158 other asteroids.

In the Southern Hemisphere, where there is no professional NEO survey, Australian John Broughton made 7,000 asteroid position measurements and 260 NEO discoveries.

Simultaneously, observers from all over the globe are setting their sights on those quiet space travelers that could sneak up on us and significantly alter the Earth as we know it. Your dues and donations translate to supplies and equipment, making Society members like you part of an around-the-globe vanguard of watchers of our skies.

Happy Birthday, SETI@home!

Five years ago, The Planetary Society helped launch SETI@home, a search for extraterrestrial intelligence that utilizes a distributed computer system. The project now operates as the most powerful computer on Earth and has racked up an impressive list of accomplishments:

- Nearly 5 million participants in 226 countries
- Nearly 2 million CPU (computer processing unit) years of work
- More than 1.3 billion results received

To celebrate SETI@home's 5th anniversary, The Planetary Society is honoring those participants who have processed the greatest amount of data over the past five years. These teams and individuals represent a broad spectrum of participants, ranging from companies that employ thousands to primary school teams for which a few individuals manage the system for the entire school. The common bond is a commitment to SETI@home, often accompanied by a little friendly competition.

We thank you, our members, for your continued support

Join us at Harvard University for our SETI Symposium

ET, Where Are You?

August 7, 2004, 9:00 a.m.–5:00 p.m.

Come and learn about the latest innovations in the search for extraterrestrial intelligence (SETI) research from the leading experts in the field, including Paul Horowitz, head of the Society's Optical SETI program; Dan Wertheimer, project scientist of SETI@home; Geoff Marcy, extrasolar planet discoverer; and many more.

Admission is $85.00, $75.00 for Planetary Society Members and SETI@home volunteers, and $65.00 for students. Attendance is limited, so there is only advance registration—no tickets will be sold at the door. To register online go to *http://www.planetary.org/setisymposium2004.html*

You can also register by mail or phone: SETI Symposium, The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106, 626-793-5100, extension 235. For additional information, e-mail us at *tps.lc@planetary.org.*

of this project. SETI@home makes it much more likely that, if it exists, the proverbial needle of extraterrestrial intelligence will be found in the haystack of the universe.

Read more about SETI@home's anniversary at *http://planetary.org/news/2004/seti_5yrs.html.*

The top 10 lists can be found at *http://planetary.org/setiteams.html.*

What's Up?

In the Sky

Planets are abandoning the evening sky as we move through June, but you can still see Jupiter easily as the brightest starlike object in the West after sunset. Venus will return to night viewing just before dawn toward the end of June and get higher in the sky through July. August will feature the Perseid meteor shower. It peaks on the night of August 11–12 and on average has tens of meteors per hour as seen from a dark site.

Random Space Fact

The surface area of Mars is approximately the same as the land surface area of Earth (i.e., without the oceans). Exploring Mars therefore is equivalent to trying to explore all the land of Earth—no small task!

Trivia Contest

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

What is the largest moon (natural satellite) in our solar system?

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

The May/June contest closes on August 1, 2004. The winner will be chosen by a random drawing from among all the correct entries received.

Our January/February trivia contest winner is James Mueller of Villa Park, Illinois.

The question was: How many instruments are on the arm of each Mars Exploration Rover?

The answer: 4 instruments—Mössbauer spectrometer, alpha particle x-ray spectrometer, microscopic imager, and rock abrasion tool

For a weekly dose of "What's Up?" listen to Planetary Radio at *planetary.org/radio*.

Bruce Betts is director of projects at The Planetary Society

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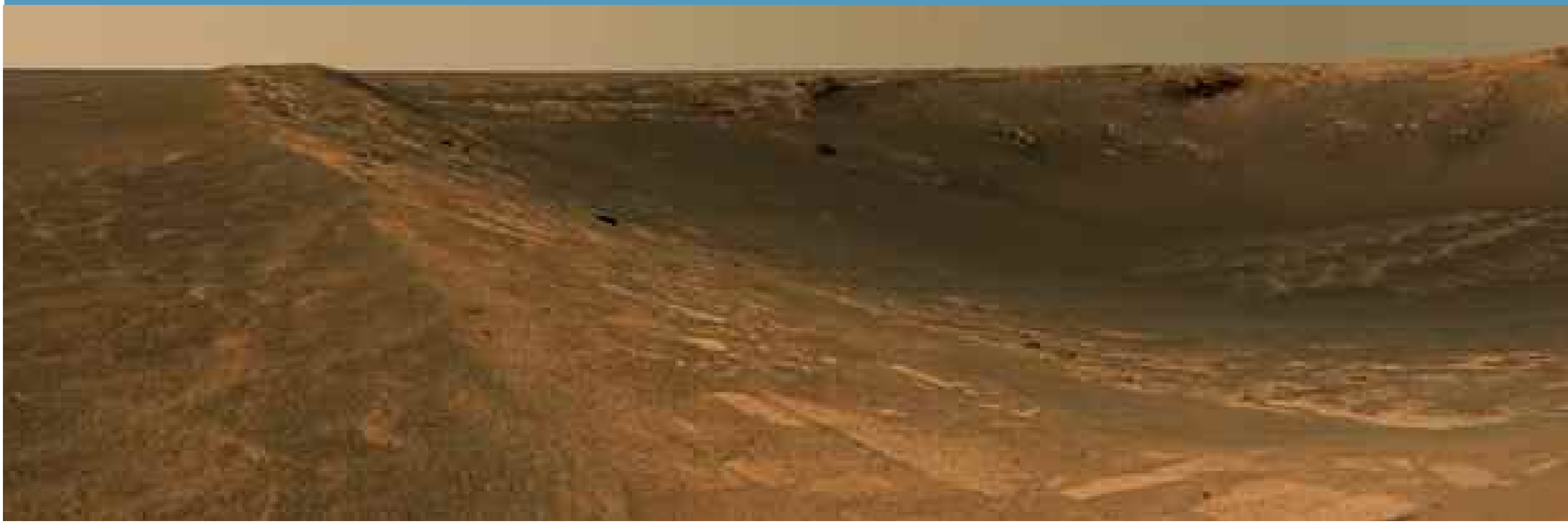


by Michael H. Carr

The latest findings by the rover *Opportunity* on Meridiani Planum have confirmed the presence on Mars of standing bodies of water at some time in the past. Why is this a breakthrough? After all, ever since the valley networks and outflow channels were discovered by *Mariner 9* more than 30 years ago, we have been discussing the possibility of vast floods, slow erosion by running water, lakes, and oceans on Mars.

The significance of the past presence of liquid water on the surface rests mainly on the possibility that some form of life might have developed on the planet. Life as we know it depends on the availability of liquid water. Today, Mars is a cold, dry desert. With mean daily temperatures around –60 degrees Celsius (around –75 degrees Fahrenheit), the ground is frozen to depths of a kilometer or more, and liquid water can exist at the surface only transiently, in small amounts, under anomalous circumstances. The chances that some form of life might have developed under present conditions are poor. But if Mars had liquid water on its surface for extended periods in the past, then the chances that life might have developed are considerably enhanced.

The Meridiani results demonstrate unequivocally that a body of water was once present there for a significant time. We do not know how long, but the layered, water lain deposits at Meridiani are thick and extensive and unlikely to be the result of a transient event. To show why this is a breakthrough, I will trace the evolution of our ideas about the role of water in Mars' evolution so we can assess the new findings in the context of our growing knowledge of the planet.

Mars' Climatic History

Apart from whether life ever flourished on Mars, the two most important things we want to know about the planet's history are how wet and how warm it was. Until

***Opportunity** spent its first 70 sols characterizing the soil and sediments in Eagle crater, where it landed. It was then sent eastward toward a prominent 150-meter-diameter crater called Endurance. On its way, it passed this 25-meter-crater containing the same evaporite rocks as are present in Eagle. On orbiter pictures of the Meridiani plains, craters are visible as bright circles in a dark background. We now know that the bright materials are evaporite outcrops and the dark materials are hematite-rich soils.* Image JPL/NASA

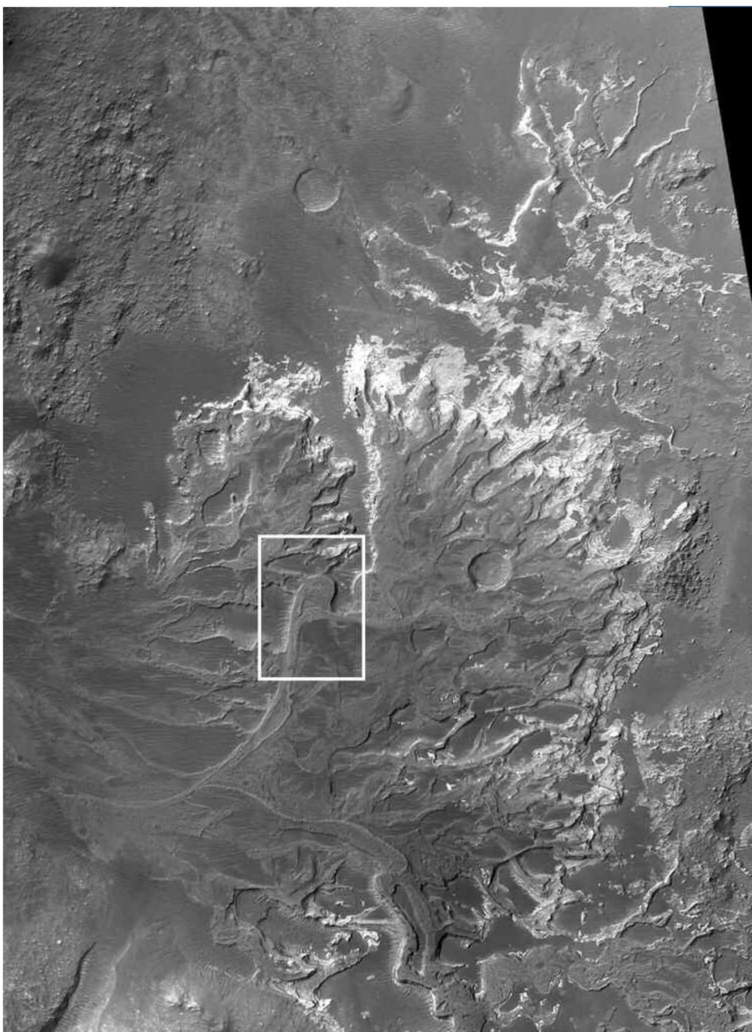
ENT WATER ON MARS

In early May 2004, **Opportunity** *arrived at the the rim of a 150-meter-diameter crater, informally named Endurance. This is what it saw as it looked east across the crater. In several places, cliffs of stratified sedimentary deposits are just below the rim. Elsewhere, the ground slopes steeply toward a dune field in the crater's center.* **Opportunity** *is now moving slowly counterclockwise around Endurance, looking for a way in. It will stop at two more points to take panoramas similar to the one seen here. We hope to complete the full circuit of Endurance by late June 2004 and then, provided we have found a safe way in, go down into the crater.*
Image: JPL/NASA

recently, the evidence that significant quantities of water existed on the surface had been largely geomorphic—that is, based on landforms. The main clues are the large channels that scar the surface, probably cut by large floods; the much smaller valley networks, probably formed by slow erosion of running water; and small gullies on steep slopes, formed more rapidly. There is also supporting evidence for pervasive ground ice and possibly ancient lakes and oceans.

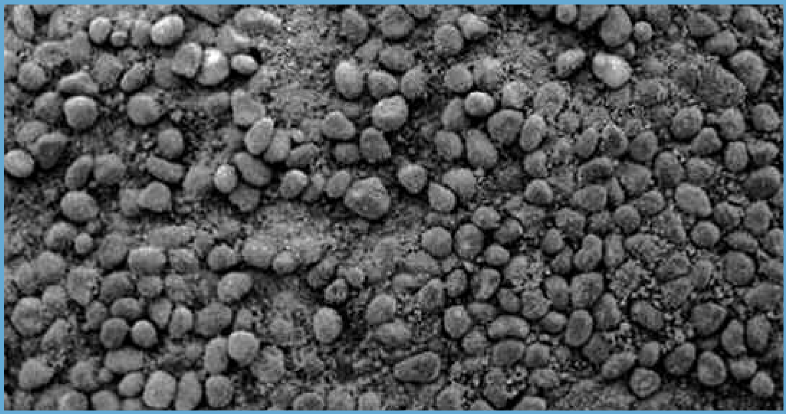
From the moment of their discovery, the water-worn features puzzled us because they implied that far more water once flowed on Mars than exists at the Martian surface today. Early estimates indicated that the equivalent of at least a few hundred meters of water spread evenly over the whole planet was needed to explain the amount of erosion caused by the large floods. The polar caps, the only known surface reservoirs, contain a few tens of meters at most. Over geologic time, another few tens of meters could have escaped from the top of the atmosphere. So, researchers wondered, where is the missing water?

There was also a problem with the climate conditions required to form the valley networks. Many of the flood channels appear to have formed by catastrophic outbursts of groundwater, and such short-lived events could occur even under the present frigid climatic conditions. The valley networks, however, appear to have formed by modest-sized streams, slowly over a long time, which implies far warmer conditions than those that now pre-



The fossilized remains of a delta lie in a crater with a diameter of 64 kilometers (40 miles) northeast of Holden crater. In wide-angle views just to the west of the area shown here, a channel can be seen incised into this crater. Extending eastward from the channel are the remains of a delta. The delta has been partly eroded away, and distributary channels within the delta survive as curvilinear ridges, probably because the channels' floors were protected from erosion by gravels. The remains of cut-off meanders (in the white box), such as we see, for example, in the lower Mississippi valley, are among the most compelling pieces of evidence we have in the orbiter data for fluvial deposition and erosion. *Image: NASA/JPL/Malin Space Science Systems*

Spirit spent the first part of its mission climbing up the rim of a 180-meter-diameter crater informally named Bonneville. This is the view looking northeast from the rim crest. *Image: JPL/NASA*



The soil at Gusev contains numerous well-rounded spherules 2 to 3 millimeters in diameter. These differ from the blueberries at Meridiani, in that they are not concretions but rounded basaltic rock fragments. Their origin is not clear. Gusev was chosen as a landing site because a large water-eroded channel enters the crater to the south. We have not, however, found any direct evidence of water-lain sediments at the landing site. The spherules may simply be rock fragments that have been rounded and sorted by the wind, but another possibility is that they are derived from nearby water-lain sediments. *Image: JPL/NASA*

vail, since the modest-sized streams would be vulnerable to freezing under present conditions

There is another problem with the source of the water. One might suppose that the valleys formed by groundwater seepage under cold climatic conditions, but there are numerous problems with this supposition. One is that the groundwater system would have to be recharged continually to replenish the losses by seepage, and this is difficult to do if the ground is frozen. Moreover, many of the characteristics of the valleys are inconsistent with an origin of groundwater seepage alone. Because of these difficulties, the valley networks were widely viewed as evidence for rainfall in a much different climate.

These problems prompted researchers to study how the Martian climate might have changed. The atmospheric pressure at the surface today is about one hundredth the atmospheric pressure on Earth. Early studies by Jim Pollack and his coworkers at NASA/Ames Research Center suggested that if the atmospheric pressure were increased to a few times the pressure on Earth, then greenhouse warming would raise the temperature above freezing and rainfall would be possible. They noted, however, that such warming would be short-lived because with a warm carbon dioxide (CO_2)–water (H_2O) atmosphere, such as Mars would have then possessed, the carbon dioxide would rapidly react with the surface rocks to form carbonates, and the atmosphere would collapse.

In later work, Jim Kasting at Pennsylvania State University pointed out that Pollack's calculations did not properly take into account cloud formation, and he concluded that no matter how thick a carbon dioxide–water atmosphere on Mars, the surface temperatures could not get far enough above freezing to enable rainfall. More refined modeling appears to confirm Kasting's conclusions. If rainfall occurred, as is suggested by the landforms, then some crucial factor is missing from the modeling.

One possible missing factor is the formation of oceans. Tim Parker and his coworkers at the Jet Propulsion Laboratory (JPL) interpreted several surface features around the northern basin as the shorelines of an ancient ocean. They proposed that the catastrophic floods, which mostly can be traced into the northern basin, left large bodies of water behind, and that these bodies of water survived long enough to leave evidence of their shorelines. Vic Baker and his coworkers at the University of Arizona suggested that these oceans temporarily changed the climate, thereby enabling formation of the younger valley networks.

That is how things stood just prior to the *Mars Global Surveyor* (*MGS*) and *Mars Odyssey* missions. These two missions compounded the mystery of water on Mars, for their data are puzzling and seemingly self-contradictory: they bolster the case for liquid water while undermining the case for warmer climates in the past.

Supporting the past presence of liquid water are Mars Orbiter Camera (MOC) images that show delta deposits with beautiful cutoff meanders, which indicate the long, slow flow of liquid water. Others show thick deposits of rhythmically layered sediments within large, flat-floored craters and elsewhere, suggesting that these features were filled with water. In addition, images from *Mars Odyssey*'s Thermal Emission Imaging System (THEMIS) reveal that many areas of the planet are far more densely dissected by valley networks than could be seen in data collected by the *Viking* orbiters in the late 1970s.

The case for a warmer climate is undermined, however, by Thermal Emission Spectrometer and THEMIS infrared spectra that reveal no trace of weathering products such as the clays, calcium carbonate, and other soluble salts that we would expect surface water to leave behind. Particularly disconcerting is the widespread presence of olivine, a basaltic mineral that readily breaks down in the presence of water. If liquid water was once prevalent on Mars, we would not expect to see so much olivine.

One interpretation is that liquid water was present for only short periods—long enough to effect enough erosion to create the landforms, but not long enough for significant weathering that would alter the minerals. Teresa Segura of the University of Colorado and coworkers suggested, for example, that large impacts would inject massive amounts of water and hot dust into the atmosphere, and this would be followed by several years of warm rainfall. Another possibility is that massive volcanic eruptions could introduce large amounts of greenhouse gases such as methane (CH_4) and sulfur dioxide (SO_2) into the atmosphere, which would temporarily warm the planet and cause rainfall.

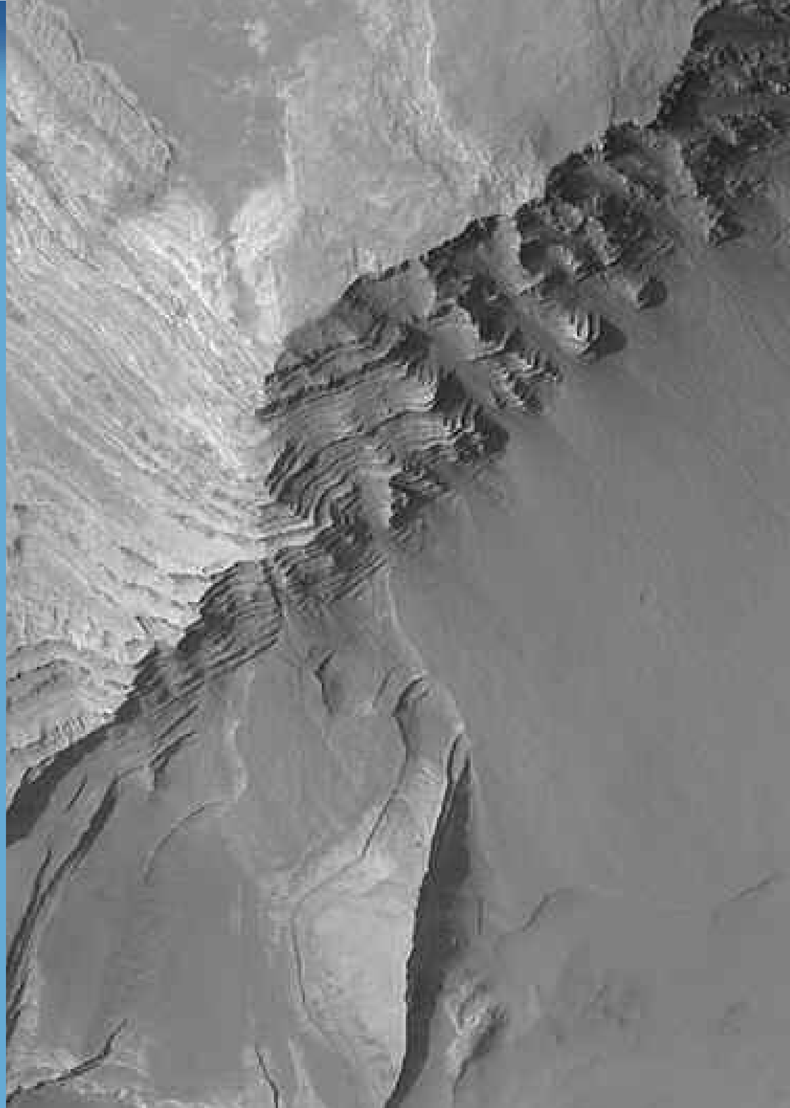
Yet another possibility is that the valleys formed during short periods of high obliquity, when Mars' spin axis was tilted more toward the Sun during summer than it is now. Water would have been driven off the poles and precipitated as ice at low latitudes. The melting of ice, either by sunlight or by volcanic heat, would result in enough runoff to form the valleys, but little weathering would occur because surface temperatures would be too low to keep the water liquid for long—not long enough to alter surface minerals.

Results from the Rovers

The Mars Exploration Rover results will help us sort through these conflicting ideas. The *Spirit* rover at Gusev crater so far has shown us little to support the supposition that water played a major role in forming the deposits across which the rover is moving. This may be the result simply of where it landed. *Spirit* is on a plain with basaltic rocks sitting on or embedded in a crumbled basaltic regolith. We know from orbital observations that different geologic units lie nearby. Parts of the floor have an etched appearance, as though an easily erodible surface unit had been partly removed to leave behind numerous mesas separated by level plains. *Spirit* is unlikely to be able to reach the etched unit, but plans are to drive it to the nearby Columbia hills.

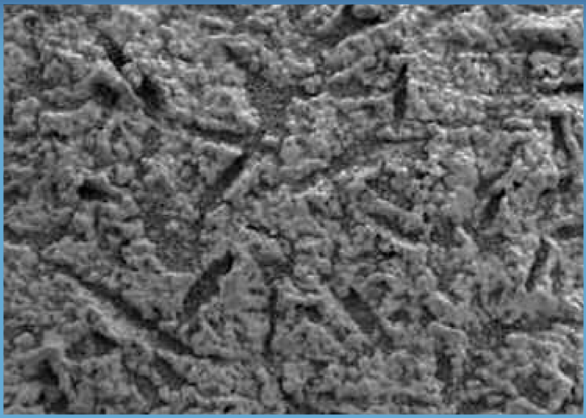
One intriguing observation from *Spirit* is the presence in the local soils of rounded granules of coarse, well-sorted, probably basaltic sand. Are these water-worn grains from some nearby water-deposited sediment? We do not know, but we will be watching closely for such sediments as *Spirit* drives toward the hills.

So far, the results from Meridiani Planum are much more pertinent to the water story. Within the small crater in which *Opportunity* landed is an outcrop of finely bedded sediments. Evidence from this outcrop indicates that

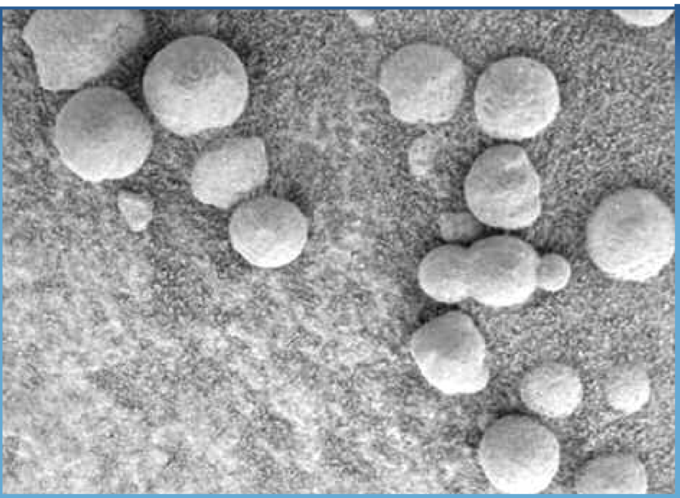


Layered deposits are clearly visible in the floor of Terby, a crater 160 kilometers (about 100 miles) in diameter. Many large, old craters in the uplands have shallow, flat floors. Where the floor has been partly eroded away, as is the case here, we see that the floor materials are finely layered. We do not know what caused the layering, but the regular rhythmic nature of the layers suggests that water was involved and that the crater formerly contained a lake. *Image: NASA/JPL/Malin Space Science Systems*

A typical outcrop at the* Opportunity *landing site in Meridiani consists of finely layered, sulfate-rich evaporite deposits in which are embedded hematite concretions. As the outcrop eroded, the more resistant concretions accumulated on the surface. *Image: JPL/NASA*



This detailed view of part of the outcrop at Eagle crater, taken by the microscopic imager, shows narrow, roughly rectangular depressions in the rock. Such depressions are common in evaporites on Earth. They result when the soft minerals erode away, leaving behind empty spaces in the rocks that retain the shape of the minerals removed. *Image: JPL/NASA*



The spherules at Eagle crater are composed of hematite. They are concretions that grew within the local rocks shortly after they were deposited and still saturated with water. Erosion of the rock has left behind a lag of concretions that covers the surface throughout the landing area. *Image: JPL/NASA*

Blue hematite spherules, or "blueberries," are liberally distributed throughout the area in which* Opportunity *landed, both in the local rocks and in the soil. The spherules are visible here eroding out of the large rock at center. A short stem attaches each spherule to the rock, and the stems may point in different directions. Exactly how this happens is puzzling, although wind is the most likely erosive agent. *Image: JPL/NASA*

Opportunity landed where there was, at one time, a body of water and that the body evaporated long ago and left behind a bedded sequence of salts.

The evidence for water here is compelling. Chemical analyses of the outcrop indicate that it is composed of 20–30 percent sulfate. Chlorine also is present, as are highly variable but lesser amounts of bromine. These are elements and compounds that become concentrated in lakes and seas that are undergoing evaporation. When the water completely evaporates, they are left behind as evaporite deposits.

We have identified one of the sulfate minerals as jarosite, a hydrated iron sulfate with minor amounts of potassium. On Earth, jarosite is known to form in the presence of liquid water. Other sulfate minerals probably are present but have not been identified because the Mössbauer spectrometer, the instrument on the rover's arm that determines mineralogy, can identify only iron mineral spherical hematite (Fe_2O_3) concretions, nicknamed "blueberries," which are liberally distributed throughout the rock and across the intervening plain. Concretions form in wet sediments on the floor of a lake or sea as salts dissolved in the water are preferentially deposited around previously deposited crystals. The sedimentary layers can be traced undeflected through terrestrial concretions, indicating that the concretions formed after the layers were deposited.

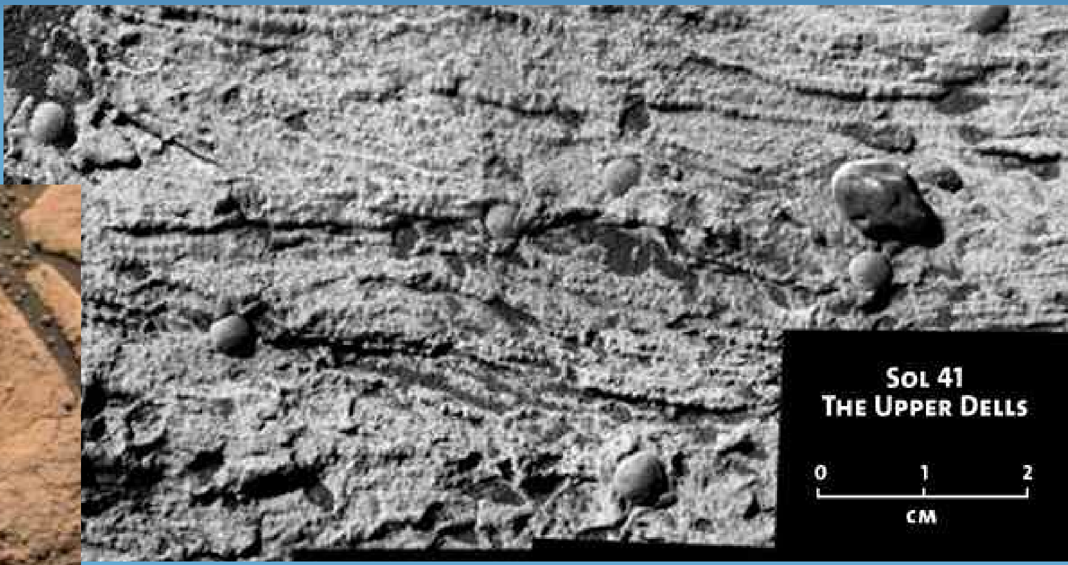
Faint layers can also be traced through some of the concretions at Meridiani. Tabular cavities in the outcrop investigated by *Opportunity*, seen by the microscopic imager, may be casts of minerals dissolved away by water or etched out by the wind.

When the composition of the outcrop was first determined, two main possibilities were considered for the origin of the high sulfate content sensed by *Opportunity*. The first is that it was deposited by groundwater circulating through sedimentary rock. An alternative is that it is an evaporite, formed of salts that were precipitated out of a body of water as it evaporated.

We can now confirm that the salts originated in a body of water. The rock shows cross-bedding and ripple marks formed by the ebb and flow of water. Cross-bedding results when beds previously laid down are transected by newer beds. The scale and nature of the crosscut relationships in the rocks at Meridiani Planum indicate that the sediments that composed them were moved by water rather than by wind.

Meridiani Planum was chosen as the landing site for a rover because *MGS* detected the presence throughout the region of a particular form of hematite that can form in aqueous environments. This hematite lies mainly in a dark geologic unit that is draped over a lighter-toned one. In places, the light unit pokes through to the surface along the crests of partly buried craters. Where the overlying dark hematite unit is absent, we can see the lighter-toned unit as a thick sequence of layered deposits that, in some areas, have been partly removed to form a highly distinctive etched terrain. The outcrop at the *Opportunity* site is likely to be an exposure of the light-toned unit. The evaporites at Meridiani Planum probably are, there-

This true-color view shows the hematite concretions sitting on and around part of the outcrop in Eagle crater. The rover's rock abrasion tool (RAT) has left behind a shallow depression 5 centimeters (2 inches) across. Use of the RAT enables us to get below the weathering rind at the surface and place instruments on the underlying unaltered rock. *Image: JPL/NASA*



Cross-bedding *is a term geologists use to describe a place in a sequence of sediments where one set of beds or layers cuts across another at an angle. The detailed relations are indicative of the processes that were occurring as the sediments were deposited. This image from an outcrop in Eagle crater shows beds in the upper left sloping down to the right to meet horizontal layers in the middle of the picture. These relations and the waviness of the bedding, which results from ripples, indicate that the beds were deposited in water. Blueberries are visible throughout the image.* Image: JPL/NASA

fore, part of a thick and now partly removed deposit of regional extent.

These evaporite deposits allow us to fill in many of the details of Mars' history. First, a large body of water once existed in the Meridiani Planum region. Second, the water in the lakes cannot have been simply surface runoff from melted ice deposits. The water had to pass through the ground to pick up the dissolved ions that ultimately were precipitated out as salts. Third, if the light-toned etched deposits are all evaporites, then large volumes of saline water must have evaporated, which implies many evaporation events over a long time or a long, continuous process of lake recharge and evaporation.

How large were these lakes? We don't yet know. There is no clearly identifiable basin that encloses all of the light-toned etched unit made of bedded deposits. Several local basins may have contained lakes. An alternative favored by Tim Parker of JPL is that the evaporites formed along the shore of a vast northern ocean. If so, then huge quantities of water must have once covered the surface.

Another crucial question we can't yet answer is whether the lakes were covered by ice. The small-scale undulations of the beds and their cross-cutting relations likely resulted from the continuous formation and reworking of ripples. Could such ripples form under an ice-covered lake? Possibly, but on Earth, ripples form much more readily on the shore of an ice-free lake than on the floor of an ice-covered lake.

These results are, of course, hugely exciting for biologists. Not only have we confirmed the past presence of open lakes or seas, but we also know exactly where to go to sample the sediments laid down in those seas. Moreover, salts and concretions like the blueberries are excellent preservers of organic remains. Meridiani Planum therefore may one day see paleontologists—robotic or human—cracking open its rocks in search of fossils.

As much as we've learned from *Spirit* and *Opportunity*, many puzzles remain to be solved. We still don't know the magnitude of any climate change. If the lakes were ice-free, then the climate had to be significantly different, but we don't know if the lakes were free of ice. If Mars has seen large climate changes, we do not know what caused them, when they occurred, and how long they lasted. We still don't know why there is almost no evidence of chemical weathering in the orbital data.

Fortunately, we are looking forward to a robust program of Mars exploration. We have three active orbiters at Mars—The US *Mars Global Surveyor* and *Odyssey* missions and the European *Mars Express* mission. These will be followed by the *Mars Reconnaissance Orbiter* to be launched in 2005, *Phoenix* in 2007, and the *Mars Science Laboratory* in 2009. The Mars Exploration Rovers have given us just a foretaste of the excitement to come.

Mike Carr is a geologist with the U.S. Geological Survey in Menlo Park, CA. He has participated in almost every mission to Mars in the last 35 years. He is a science team member on the Mars Exploration Rover.

CASSINI AND HUYGENS ARI
A GRAND ADVENTU

Cassini-Huygens *is closing in*
system. On May 16, 2004 Cass
about 13 degrees below Satur
of three images (through red,
million kilometers (15 million
one of Saturn's major moons.

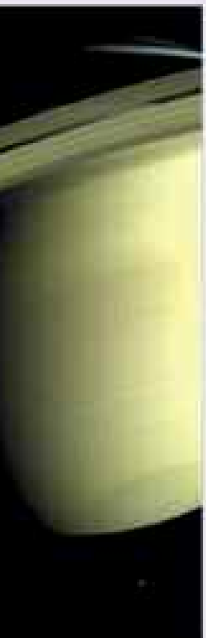
Left: **Cassini-Huygens** ***blasted off from Florida's Cape Canaveral on October 15, 1997. Its seven-year voyage to the Saturnian system will culminate on June 30, 2004.***
Photo: Kennedy Space Center

by Dennis L. Matson and Linda J. Spilker

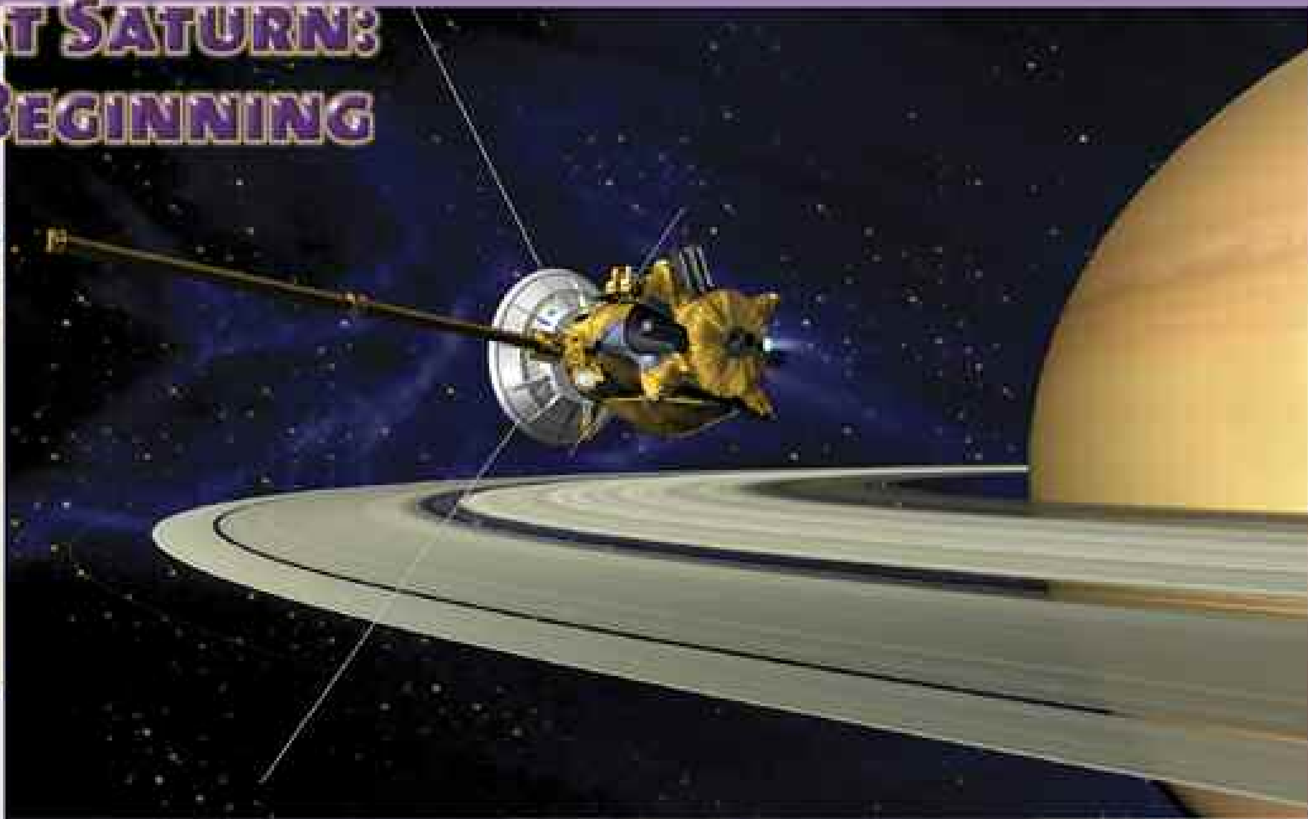
The *Cassini* orbiter and the *Huygens* probe are now exploring the magnificent and mysterious planet Saturn, its emblematic rings, and its extended family of at least 31 moons. They are not the first robots sent from Earth to investigate this planetary system—*Pioneer 11* in 1979, *Voyager 1* in 1980, and *Voyager 2* in 1981 blazed the trail for future explorers—but together they constitute the most complex and ambitious mission ever sent to another world. There is no doubt that, over the next several years, we will be continually surprised, dumbfounded, and delighted with the discoveries they will radio back to us on Earth.

Saturn is one of the five planets visible to the naked eye, and virtually every ancient civilization marked its

RIVE AT SATURN:
RE IS BEGINNING



from the south on its final target—the glorious Saturnian
sini took this picture with its narrow-angle camera from
n's equator. This picture was made using a combination
green, and blue filters). It was taken at a range of about 24
miles). The tiny white dot near the south pole is Enceladus,
Image: JPL/NASA/Space Science Institute



Cassini-Huygens *is starting to enter orbit around Saturn in this artist's conception. It has crossed Saturn's ring plane from below, and one of its main engines has just begun firing to reduce the spacecraft's velocity with respect to the planet. This braking maneuver will be about 97 minutes long and will allow* **Cassini-Huygens** *to be captured by Saturn's gravity into a five-month orbit from which it will observe the planet and its rings at very high resolution.* Illustration: JPL/NASA

progress across the sky. It is the second most massive planet in our solar system—95 times the size of Earth—and its ring system is by far the most extensive and beautiful yet seen. Among its retinue of moons is Titan, the size of a planet itself, with a thick nitrogen atmosphere colored orange by a rich soup of hydrocarbons.

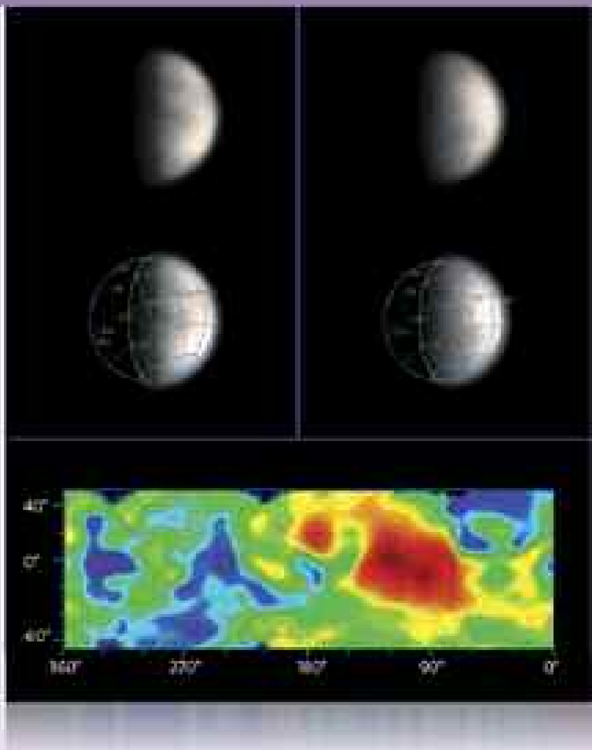
Cassini will also explore the huge Saturnian magnetosphere—that region in space where the planet's magnetic field overpowers the solar wind, which consists of the solar magnetic field and charged particles from the Sun, and diverts their flow around the planet. Each of the remarkable collection of icy moons is a new world to explore. We look forward to close encounters with Mimas, with a giant peaked crater that makes it a dead ringer for the Death Star in the *Star Wars* films; Iapetus, with one side very black and the other icy white, looking like a yin-yang symbol; and many other unique worlds.

Cassini-Huygens is designed to study the Saturn system systematically so that we can better understand the interactions among the planet, its rings, its moons, and its magnetosphere. We can draw an analogy to a mechanical clock. A clock has many parts, but describing each part and cataloging its mechanical properties would completely miss capturing the essence of a clock. The essence is in the interaction among the parts.

In terms of the Saturn system, capturing the essence requires that the observation spacecraft be able to take measurements with several instruments simultaneously, while at the same time taking into account time; location and direction relative to the Sun, Saturn itself, and the moons; latitude and longitude within the magnetosphere; and the state of the solar wind. The demands of such a system explain why *Cassini-Huygens* is the largest spacecraft ever sent to the outer solar system.

It is also a two-part mission. On December 24, the *Cassini* orbiter, operated by the Jet Propulsion Laboratory for NASA, will release the *Huygens* probe, operated by the European Space Agency, on a trajectory that will deliver it to Titan on January 14, 2005. As it falls through the dense nitrogen atmosphere, *Huygens* will collect data on that atmosphere's composition, winds, and structure. We know from the *Voyager* flybys that the atmosphere on Titan is rich in hydrocarbons—such as methane, ethane, and acetylene—and modeling of these compounds' behavior suggests that ethane-methane seas may exist on this moon's surface. *Huygens* is equipped for such a possibility: it carries a surface science package that can measure the rocking of the probe should it land atop a wavy sea.

Together, *Cassini* and *Huygens* will conduct 27 scientific investigations with the most capable and sophisticated set



In mid-April 2004, Cassini *gave us this glimpse of Titan's surface in these images taken through one of the narrow-angle camera's filters. The filter transmits light in the near-infrared (at a wavelength of 938 nanometers), which is invisible to human eyes. Titan rotated 90 degrees in the four days that elapsed between the upper right and upper left images. The images in the center show Titan's orientation—they were taken from 17 degrees below the equator. Hubble Space Telescope data were used to construct the map of Titan's surface at the bottom of the figure.* *Image: JPL/NASA/Space Science Institute*

of instruments ever sent to the outer solar system. We expect to be deluged by the data from these investigations: on "high-activity" days, *Cassini* will send four gigabits of data for us to process and understand.

The Expedition So Far, and Plans for the Future

On October 15, 1997, *Cassini* and *Huygens* began their expedition with a launch from the NASA Kennedy Space Center. That was the first step in a nearly seven-year trip to reach the orbit of Saturn, which orbits at a mean distance of 1.4 billion kilometers (about 875 million miles) from the Sun, or 9.5 times the distance of Earth from our system's central star.

On the way, the spacecraft passed close by Jupiter on December 30, 2000, picking up a boost from that giant planet's gravity—as well as giving the mission team a rehearsal of operations at Saturn. We also took advantage of the fact that the *Galileo* orbiter was still operating within the Jovian system. The two spacecraft worked together, *Galileo* inside Jupiter's magnetosphere and *Cassini* outside it, to gather some extraordinary data on how the solar wind and the huge magnetosphere interact with each other. Later, the situation was reversed with *Galileo* outside the magnetosphere and *Cassini* inside it.

At Saturn, the *Cassini-Huygens* mission will go through three main phases: arrival and insertion into orbit, the *Huygens* mission at Titan, and the orbital tour through the intricate system of moons.

We began taking observations months before actually reaching the system to refine our knowledge of Titan, the rings, and the planet as soon as possible. Looking through 42 filters on two cameras in the imaging system, we've penetrated the enshrouding haze to see clouds or surface features on Titan. Clumps in the thin F ring are already visible to the spacecraft, and we've been able to track storms through the giant planet's atmosphere and watch them merge.

At 11.3 million kilometers (7 million miles) from Saturn, on June 11, we will pass the small moon Phoebe, whose diameter is only 150 kilometers (95 miles). This is a particularly unusual world because its orbit around Saturn is highly inclined and retrograde (backwards, compared with other moons in the system). Phoebe and a dozen recently discovered small objects orbiting Saturn probably once were on interplanetary trajectories, perhaps ejected from the Kuiper belt beyond Neptune. They traveled too close to the giant planet and were captured by its gravity.

These characteristics make us keen to understand more about tiny Phoebe. We will make only one flyby, so during our pass 2,000 kilometers (1,250 miles) above its surface, we will take measurements to determine its density, which will give us clues to its bulk composition. We are expecting to see craters on the surface—*Cassini-Huygens*' close flyby should tell us for sure.

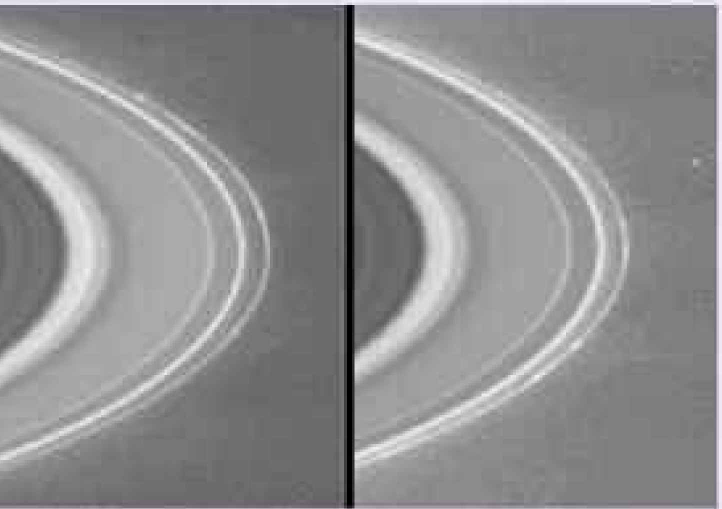
As we approach the planet, we will experience one of the most exciting and nerve-wracking moments in the mission: *Cassini-Huygens* will actually fly through the rings of Saturn—twice. This is safer than it probably sounds. *Pioneer 11* and *Voyager 2* also passed through regions encompassed by the rings, and we have chosen for our pass a region that is empty of ring particles. Should we encounter any bits of dust, we expect them to be very small and light—the size of smoke particles—and the spacecraft is designed to withstand such impacts.

The spacecraft will come in from beneath the E ring, and at 1.86 hours before closest approach to the planet, we'll fly between the F and G rings. The orbit-insertion trajectory will take us down through the rings again at 1.9 hours after closest approach, at which point we'll be only 18,000 kilometers (about 11,200 miles) from the giant planet.

Obviously, this is a unique opportunity to make observations. However, during the orbit insertion burn itself, only the fields, particles, and wave instruments will operate. These instruments do not need to be "pointed." The main engine will fire for 97 minutes to change velocity by 633 meters per second and drop the spacecraft into orbit about Saturn while keeping the spacecraft optimally pointed. It will take about five minutes after the engine shuts off for sloshing in the propellant tanks to subside.

Once orbit insertion is complete, the spacecraft will start pointing its remote-sensing instruments, including the cameras, to take a close-up look at the rings. The viewing angle will be low, only 20 to 30 degrees from nadir, but that angle is a compromise between the desires

The Cassini-Huygens *team began making observations well ahead of the spacecraft's arrival at Saturn. At left, we see the planet as we're more familiar with it—in a visible light image taken by the Imaging Science Subsystem (ISS). At right is an image taken by the spacecraft's Visible and Infrared Mapping Spectrometer (VIMS). Comprising two cameras, VIMS will capture images using visible and infrared light to learn more about the composition of the atmospheres of Saturn and Titan, as well as those of Saturn's rings and the moons' surfaces. With VIMS, scientists also plan to perform long-term studies of cloud movement and morphology in the Saturnian system to determine the planet's weather patterns.* *Image: JPL/NASA*



These two images, taken on February 23, 2004, show "clumps" of ring particles in Saturn's F ring. The narrow-angle camera on Cassini *took these pictures from a distance of 62.9 million kilometers (39 million miles). These clumps revolve around the planet. In the second image, the white dot at center right is Saturn's small moon Janus, which is 181 kilometers (112 miles) across.*

Image: JPL/NASA/Space Science Institute

Two of Saturn's tiny moons, Prometheus (102 kilometers, or 63 miles, across) and Pandora (84 kilometers, or 52 miles, across), are visible here shepherding (confining from both sides) the planet's narrow F ring. Slightly above the pair and to the right is Epimetheus, which is 116 kilometers (72 miles) across. Cassini*'s narrow-angle camera took this picture on May 1, 2004 from a distance of about 31 million kilometers (about 20 million miles). The image has been magnified and greatly contrast-enhanced to aid visibility.*

Image: JPL/NASA/Space Science Institute

of the magnetic field investigators and those on the remote-sensing teams. At closest approach to Saturn is the only time that this portion of the magnetic field will be available for measurement; it is also the best time to view the rings up close.

Cassini and *Huygens* on Their Own

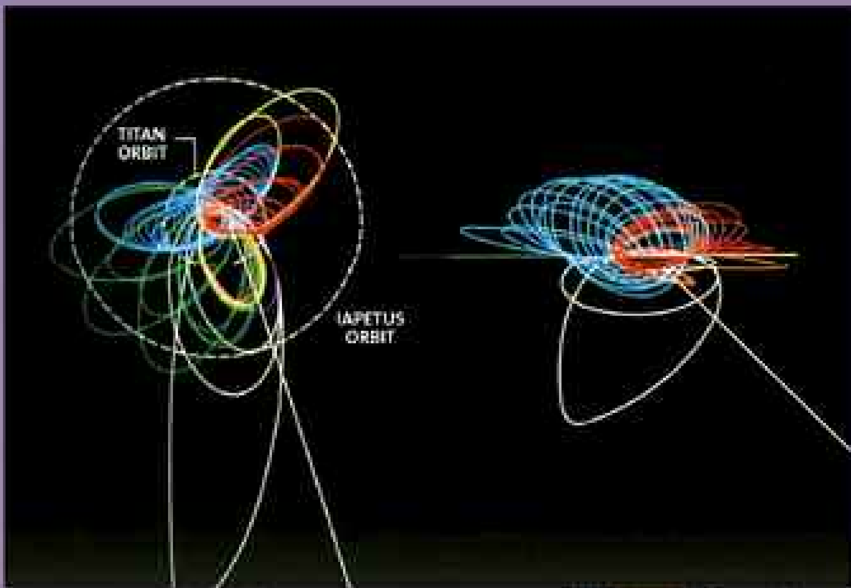
The first two orbits about Saturn are designed to set up the trajectory necessary to deploy the *Huygens* probe. On December 16, three days after the end of the second orbit, the probe-targeting maneuver will place *Cassini-Huygens* on a course that will intersect Titan. *Cassini* will then turn and aim *Huygens* at the large, smog-enshrouded moon. On December 24, the orbiter will release the probe.

After delivering *Huygens*, *Cassini* will swing off into orbits that will take it past the icy satellites to explore much of the volume of the magnetosphere as well as to high latitudes above the planet to observe the rings. The spacecraft will use 45 close flybys of Titan both to study the giant moon and to use Titan's gravity to change its orbit. Titan is the only satellite large enough to significantly alter the orbit. The smaller icy satellites sometimes can help with small perturbations that can be useful in trimming a trajectory.

The mission plan calls for 76 orbits around Saturn. The orbits' sizes, orientation to the Sun-Saturn line, and inclination to the planet's equator are gauged to meet scientific requirements. These include the following:

- Titan ground-track coverage, to give the radar instrument a chance to penetrate the thick atmosphere and give us detailed images of the veiled surface
- targeted flybys of the icy satellites and Saturn itself so that scientists can get close looks at the many intriguing geologic features of the moons and the atmospheric dynamics of the planet
- ring occultations, whereby the spacecraft will allow ring particles to pass between it and the Sun and Earth, enabling scientists to learn much about the nature of the particles
- orbits that take the spacecraft over the planet's polar regions and allow it to look directly down upon the complex and extended ring system
- ring-plane crossings, when the spacecraft and its instruments will be able to look at the rings edge-on.

During many of the Titan flybys, the radar investigation will use a synthetic aperture radar (similar to the instrument *Magellan* used to return spectacular images of



Cassini-Huygens*' tour of Saturn's system is broken into color-coded time segments here.*

- *The outer dotted circle corresponds to the orbit of Iapetus and the inner one to Titan's.*
- *White indicates the period from July 1, 2004 to February 15, 2005, and it includes orbit insertion, the probe release, and the* Huygens *mission.*
- *Violet shows February 15 to April 1, 2005, which includes the first close Enceladus flyby.*
- *Orange, which includes a series of important ring and Saturn occultation sequences, is from April 1 to September 7, 2005.*
- *Green represents the period between September 7, 2005 and July 22, 2006, during which the magnetosphere and magnetotail will be mapped.*
- *Blue covers July 22, 2006 to June 30, 2007 and includes a 180-degree transfer out of the ring plane.*
- *Yellow shows June 30 to August 31, 2007 and includes flybys of Iapetus and certain icy satellites.*
- *Red goes from August 31, 2007 until the end of the primary mission on July 1, 2008, and it consists mainly of the high-inclination sequences that sample the energetic particles along the magnetic field lines associated with the aurora.* *Illustration: JPL/NASA*

For a more detailed description of Cassini-Huygens*' tour, visit*
http://planetary.org/saturn/cassini_tour.html

The many parts of Saturn's magnificent and complex system of rings are shown here from the top of the planet.

Illustration: Don Davis, courtesy of Sky & Telescope

Venus), an altimeter, and a radiometer to study the surface. Data from these instruments should help us determine whether Titan has hydrocarbon oceans and, if so, where and how large they are. Radar observations from Earth have told us that there is ice of some sort and possibly geologic features like mountains on Titan, and the radar should help us map those as well.

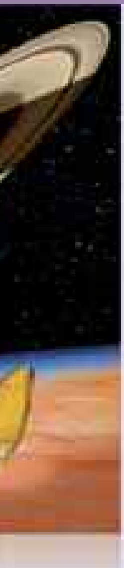
The Saturnian magnetosphere is large and structured, and we hope to take the magnetic fields instruments through as many of its parts as possible to measure the strengths of the fields and the compositions of the plasmas that fill the magnetosphere. Our goals are to build a three-dimensional model of Saturn's magnetosphere and to determine the magnetic states of the moons and how they interact with the planet's encompassing region of magnetic influence.

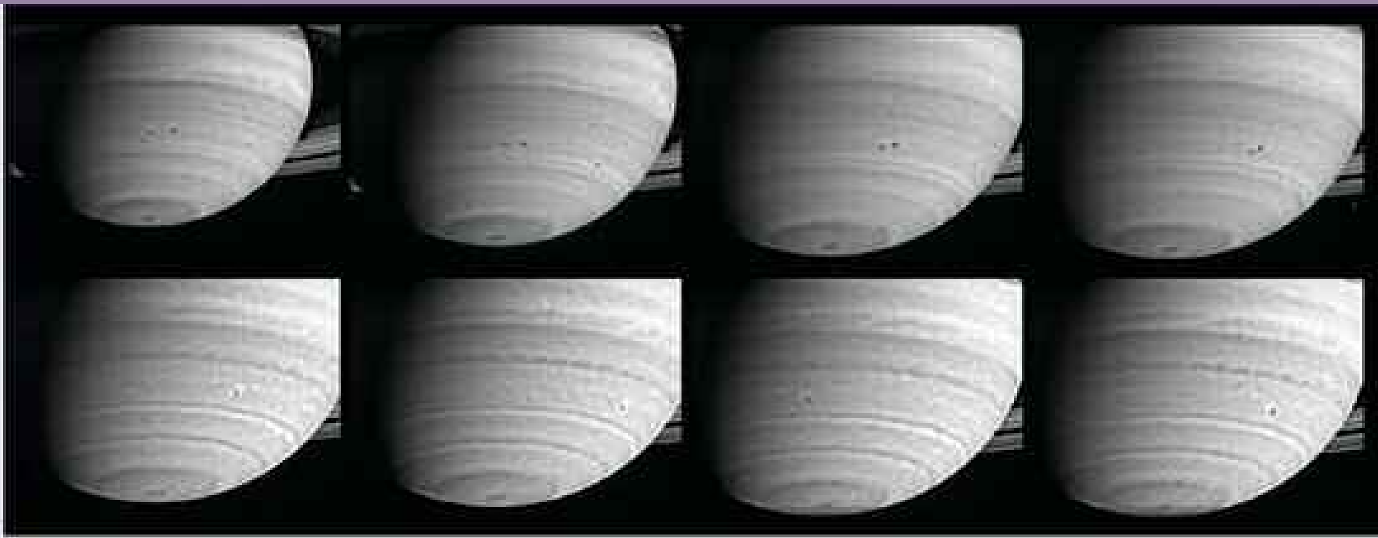
Mimas, Enceladus, Tethys, Dione, Rhea, and Iapetus are the largest of Saturn's icy moons, and our orbital tour will take us into and out of their orbits. The *Voyager* spacecraft gave us intriguing glances of these strange and varied worlds, and planetary scientists are eager to get even closer looks at them.

Iapetus is a good example of a world that merits a closer look. Its surface is split between dark regions (blacker than pitch) and bright regions (whiter than snow), and the boundaries between these regions are sharply drawn. The dark regions may be covered with organic compounds, and pinning down their origin is a prime puzzle to be solved.

The icy satellites taper down in size, from Titan (larger than the planet Mercury) to the particles that make up the magnificent rings. Ring particles are chunks of ice that range in size from that of a house to smaller than a dust mote, and each particle is itself a moon of Saturn.

The larger chunks that we call satellites interact with ring particles in ways we only partially understand. The thinner rings, such as the F ring, are constrained in





Above left:* Huygens*' observations of the complex organic chemistry of Titan may give us clues as to how life began on our own planet. In this artist's conception, the probe has separated from the* Cassini *orbiter and is headed down through the murky depths of Titan's atmosphere.

Illustration: David Ducros for the European Space Agency

Above: Three months away from its arrival at Saturn,* Cassini *observed two storms in the act of merging. With diameters close to 1,000 kilometers (620 miles), both storms, which appear as dark spots in the southern hemisphere, were moving west (relative to the rotation of Saturn's interior) for about a month before they combined on March 19 and 20, 2004.

These eight images were taken between February 22 and March 22, 2004. The top four frames, which are portions of near-infrared images, span 26 days. The bottom frames are from images taken on March 19, 20, 21, and 22 in a wavelength visible to the human eye. This sequence illustrates the storms' evolution. Just after the merger on March 20, the new feature showed north-south elongation with bright clouds on either end. By March 22, the storm had settled into a more circular shape with a halo of bright clouds around its circumference.

Image: JPL/NASA/Space Science Institute

shape and extent by so-called shepherd satellites. In April, *Cassini* was able to see Prometheus and Pandora, and as the mission continues, we'll be watching these shepherds even more carefully.

Among the most surprising discoveries of the *Voyager* spacecraft were the "spokes" in Saturn's rings. These radial features, which resemble spokes on a wagon wheel, come and go, and they may be dust that is elevated above the ring plane by electrostatic forces. *Cassini* will study these features in detail.

For centuries, scientists have known that Saturn's rings, which looked to early observers like a solid disk around the planet, actually are divided into discrete sections. The major divisions are called the A, B, and C rings. We see distinct color differences among them, which tells us that they have differing compositions. *Cassini*'s visible and infrared mapping spectrometer will take measurements that should help us determine these compositions.

The rings and moons of Saturn are fascinating objects for study—but no less fascinating is the planet itself. Even from Earth, observers can see subtle banding and color variations in the butterscotch-colored atmosphere. These bands are governed by the winds of Saturn. These winds are powerful; at the equator, *Voyager* measured speeds of 500 meters per second.

The dynamic atmosphere calls up huge storms that rage across the planet's face. Sometimes, these storms collide and combine, and during its approach, *Cassini* observed this process in action. This is only the second time this rare occurrence has been imaged.

With all this and more to be explored in the Saturn system, we are expecting an incredible mission yielding fascinating data. The *Cassini-Huygens* mission is a joint undertaking by NASA and the European Space Agency, with the partnership of the Agenzia Spaziale Italiana, and it is one of the most ambitious voyages of exploration ever attempted. We know the discoveries will be astounding, and we look forward to sharing them with people around the world.

Dennis L. Matson is the Cassini *project scientist and a senior research scientist at NASA's Jet Propulsion Laboratory (JPL). He finds international missions very exciting because they bring together the best scientists in the world to work on challenging problems, promoting better understanding between people and promoting peace.*

Linda J. Spilker is a principal research scientist at JPL and is the Cassini *deputy project scientist and a co-investigator on the* Cassini *Composite Infrared Spectrometer team. Linda is also a scientific spokesperson for the space program, engaging in public outreach activities for students of all ages and the general public. For more information on Linda Spilker, see the NASA Solar System Exploration website at* http://solarsystem.nasa.gov/people/profile.cfm?Code=SpilkerL.

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World Watch

by Louis D. Friedman

Washington, DC—The major political question concerning space now is what will happen to the proposed human space exploration policy in the United States. Still in search of a permanent name, it is variously called "Vision for Space Exploration," "Moon to Mars," and "Moon, Mars and Beyond."

President Bush proposed the new policy in mid-January, and the NASA budget submission to Congress for the fiscal year beginning in October 2004 contains approximately $800 million to implement it. Of that increased budget, however, $650 million is directed to the shuttle for changes to accommodate its reflight, and $80 million (plus other funds reallocated from the cancelled Orbital Space Plan) is for the new Crew Exploration Vehicle to replace the shuttle. The remaining $70 million is allocated for specific preparations of new Moon-to-Mars programs. These include two new US missions to the Moon (see note below) and studies on new robotic missions to Mars beyond 2009. A Mars sample return will specifically be studied.

The budget proposal provides funds for the first five years of the new strategy, but not for the human missions that will land on the Moon and Mars. Those costs are deferred until the implementation of those missions is better defined.

The Planetary Society strongly supports the new policy—see *www.aimformars.org*. Unfortunately, in Congress it has been greeted by a great deal of uncertainty and some skepticism. Although the policy is presented more as a strategy for the space program than as a complete plan, some in Congress still seek full cost estimates for a defined program.

The congressional process is complicated: each year, proposals must pass through three sets of committees in the House and in the Senate (budget, authorization, and appropriations). Then, Congress votes on each committee's version before the president signs the final bill. This year, election politics dominate, and it is likely that final action on the budget will not be completed before the new fiscal year begins. That delay could force NASA to begin work on the new policy with the old budget.

In addition to controlling the budget, Congress can also direct NASA to do, or not do, certain things. It does this by putting language in committee reports. Many programs (including NASA's SETI program and earlier studies of human missions to Mars) have been killed by such committee language.

As we go to press, the Senate Budget Committee has passed the NASA budget proposal as the White House submitted it, including the new policy; the House Budget Committee did not. In fact, it cut NASA's funding. This difference must be resolved before other congressional committees take action.

The Society is monitoring the US Congress' budget considerations and the status of the new policy. We will keep our members informed and involved. Follow the action on our website, *http://planetary.org*.

The Moon—The new exploration policy calls for NASA to launch a lunar orbiter in 2008 and a lunar lander/rover in 2009. These missions will investigate specific questions related to human missions in the next decade.

After three decades of being almost ignored, the Moon will soon be a busy place for robotic spacecraft. Europe has a mission now on the way to the Moon, *SMART-1*. It is a technology test of low-thrust propulsion and will take some 16 months to reach the Moon. Once there, it will measure surface chemical composition, including the materials in the polar regions, which may hold traces of ice.

Japan has been developing *Lunar-A*, a lunar orbiter that will fire penetrators into the surface, and *SELENE*, an orbiter that will deliver two smaller satellites to lunar orbit. India is planning a lunar orbiter, *Chandrayaan-1*, and China has described *Cheng'E* as a lunar program with two missions—an orbiter and a lander. All these missions are planned for launch this decade.

Cooperation among all these countries in exploring the Moon would make sense, especially given the new US exploration priorities. The Planetary Society took the lead in trying to make this happen with an international workshop in Beijing at the end of May. We will report on that in a future issue.

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

Questions and Answers

How can we be sure that comets such as C/2001 Q4 (NEAT) and C/2002 T7 (LINEAR) are [or were] new comets, instead of being old comets that somehow changed their trajectories?
—Joao Miguel Matos
Setubal, Portugal

When we say that these two comets are "new," we mean that they probably have come to the vicinity of Earth for the first time (see photo below). Orbit calculations suggest that they have both come in from the Oort cloud, with aphelion (point farthest from the Sun) distances of, say, 50,000 astronomical units (an astronomical unit, or AU, is the distance from the Earth to the Sun, about 150 million kilometers or 93 million miles). According to these calculations, both comets spent two million years on the journey.

Dutch astronomer Jan Oort noticed around 1950 that most comets come from such great distances, except for the short-period comets that have their aphelia near the giant planets. When longer-period comets come to the vicinity of the planets, the gravitational influences of those planets generally will change the comets' aphelion distances quite significantly, causing many to drop to 10,000 AU and less. Under these circumstances, many other comets might even be expelled from the solar system on hyperbolic orbits.

If comets are shifted into smaller orbits, they should return after shorter times. We should expect, indeed, to see many comets coming in from closer distances—but we don't. Therefore, most of the comets we see must be coming in for the first time. Either something is causing the number of really distant comets to increase, or something is making it less likely that we find, on their returns, those that don't go out very far.

Comet NEAT as it appeared on May 8, 2004 over Joshua Tree National Park in California.
Photo: Wally Pacholka

The consensus among scientists is that the latter is the case, with the "something" being a fading in brightness during and after the comet's first pass that makes it less likely that we will observe it on its subsequent passes. Such fading perhaps is a result of the loss of a comet's most volatile material, which gives a comet its characteristic fuzzy look and long tails. Obviously, this can cause an initially promising comet to fizzle out. Although any comet can become a dud, we should be particularly conscious of those that seem to be "new."

Of course, we don't know for sure that a comet coming from an aphelion of 50,000 AU is a first-timer. It could just be that the gravitational effect of the planets on its last visit caused the comet's aphelion to end up there. Most such comets must be first-timers, and if they do fizzle, they almost certainly are.
—BRIAN G. MARSDEN,
Harvard-Smithsonian Center for Astrophysics

In the many articles I've read about the Mars Exploration Rovers, several aspects of their design have been discussed. Yet I've seen no explanations for the small sizes of the wheels. I think 25 centimeters (10 inches) is small for covering rough, regolith-like country. I work in the Sahara Desert, and no vehicle with such small wheels would work well in most locales. Can you please explain the design rationale?
—Rufus Churcher
Gabriola Island, British Columbia, Canada

We made the wheels as large as we possibly could. We were limited by what we could fit inside the lander, which then had to fit into the entry vehicle (or aeroshell), which, in turn, had to fit onto the launch vehicle. Even then, we had to cut holes in the lander for the wheels to protrude into.

As you point out, bigger wheels are better for loose regolith. We wanted to spread the weight of the vehicle over as large an area as possible to minimize sinkage. The rovers were designed to respond to the ground below them in terms of the amount of pressure that ground can support. The rovers' wheels will sink just far enough so that the weight of the vehicle is spread over the wheel area in order to equalize that pressure. Wider wheels with larger diameters help, but the biggest wheels we could fit were 16 centimeters (6.3 inches) wide and 26 centimeters (10.3 inches) in diameter.

Compared to vehicles used in the Sahara, our rovers on Mars have two things in their favor. First, they have six wheels instead of the much more common four—and we've done a pretty good job of evenly distributing the spacecraft's weight among those wheels. Second, because the gravity on Mars is only 38 percent of Earth's gravity, the effective weight on the wheels is that much less, which again results in less wheel sinkage in the soft Martian soil.
—RANDEL A. LINDEMANN,
Jet Propulsion Laboratory

Factinos

Significant amounts of icy organic materials have been discovered sprinkled throughout several "planetary construction zones" or dusty disks that circle infant stars. Dan Watson and William Forest of New York's University of Rochester identified the ices using NASA's Spitzer Space Telescope. They surveyed five very young stars in the constellation Taurus, 420 light-years from Earth. Previous studies identified similar organic materials in space, but this is the first time they've been seen unambiguously in the dust that makes up planet-forming disks.

These materials, icy dust particles coated with water, methanol, and carbon dioxide, may help explain the origin of icy planetoids like comets.
—from the California Institute of Technology and NASA

The Spitzer Space Telescope has also discovered two of the farthest and faintest planet-forming disks ever observed. Spitzer's exquisitely sensitive infrared eyes can see planet-forming disks in great detail. The newly discovered disks surround two of more than 300 newborn stars seen for the first time in a stunning new image (below) of the dusty stellar nursery called RCW 49, which is about 13,700 light-years from Earth in the constellation Centaurus.

"Preliminary data suggest that all 300 or more stars harbor disks, but so far we've only looked closely at two. Both were found to have disks," said Ed Churchwell of the University of Wisconsin, Madison, principal investigator of the RCW 49 research.
—from the California Institute of Technology and NASA

Planet-forming disks have been detected around two infant stars in one of the Milky Way's most prolific stellar nurseries, a nebula called RCW 49. This infrared image is composed of pictures taken, in four different wavelengths, on December 23, 2003 by NASA's Spitzer Space Telescope.

Image: JPL-Caltech/NASA/ E. Churchwell

The Bounce Rock—so named because* Opportunity*, still encased in airbags, literally bounced off it on landing day—shows a striking similarity in spectra to two well-known Mars meteorites on Earth—EETA 79001 and Shergotty. This false-color composite shows the rock after the Mars Exploration Rover* Opportunity *drilled into it with its rock abrasion tool.

Image: JPL/NASA/Cornell

Opportunity has examined an odd volcanic rock (above) called Bounce Rock at the rover's Meridiani Planum landing site and found that it is unlike anything previously found on Mars. However, it's a lot like a couple of meteorites found on Earth—EETA 79001 and Shergotty. Bubbles of gas trapped in these meteorites match the recipe for Mars' atmosphere so closely that scientists have been confident for years that these rocks originated from the Red Planet. But spacecraft examinations of rocks on Mars have never found any rocks like them until now.

"We think we have a rock similar to something found on Earth," said Mars Exploration Rover science team member Benton Clark of Lockheed Martin Space Systems in Denver. The similarity seen in data from *Opportunity*'s alpha particle X-ray spectrometer "gives us a way of understanding Bounce Rock better," Clark said.
—from the Jet Propulsion Laboratory

Society News

We're Aiming for Mars!

Thank you, members. Your response to our Aim for Mars! letter is enabling us to provide funds to advocate that the United States and other spacefaring countries focus their space exploration efforts on Mars. In a significant step, we have engaged Lori Garver as the Washington, DC representative for The Planetary Society. From 1998 to 2001, Ms. Garver served as the associate administrator for Policy and Plans at NASA. Before that, she was executive director of the National Space Society.

We also have initiated three technical studies in support of the Moon-to-Mars national space policy. The study on space transportation is led by retired astronaut Owen Garriott and by Michael Griffin, the Space Department head at the Johns Hopkins Applied Physics Laboratory. The second study, led by Bruce Betts, Society director of projects, concerns developing a test bed for a Mars outpost on the Moon, called the Lunar Waystation. In the third study, Russian engineers will investigate how to transport human explorers to the Moon and on to Mars. These studies will provide us with the necessary background to take strong political positions advancing human exploration of Mars.

The Aim for Mars! campaign was launched publicly in the first week of May, coinciding with testimony by Society Executive Director Louis Friedman to the President's Commission on the Implementation of US Space Policy. We are urging our members to send their friends to *http://aimformars.org* to sign the petition in support of Aim for Mars! We will deliver the signed petitions to space leaders and decision makers worldwide.

Finally, The Planetary Society joined with other space advocacy organizations and aerospace companies to issue a joint press release supporting the Moon-to-Mars policy in the US Congress.

With your support, we really can make it happen.

—Louis D. Friedman,
Executive Director

Planetary Radio Coming to Your Airwaves

Have you heard the Society's radio series? Planetary Radio has been airing on 88.9 FM, KUCI, in Irvine, California for more than a year. The weekly show can be heard every Monday at 5:30 p.m. Pacific Time. We're proud to announce that WMUH in Allentown, Pennsylvania has just added Planetary Radio to its schedule. Listeners in the Lehigh Valley can now hear us every Monday at 9:30 a.m. Eastern Time at 97.1 FM.

Planetary Radio will soon be available to hundreds of other public radio stations via National Public Radio's Public Radio Satellite Service. Let us know if there's a station near you that should be carrying our program by e-mailing us at *planetaryradio@planetary.org*. Better yet, let the program director of your local station know that public radio's best-produced and most informative series about space exploration is available at no charge.

In the meantime, you can also listen at our website. Visit *planetary.org/radio*. The current and all past programs are always available for easy downloading and streaming. You'll hear our great guests, special events, space exploration news, and fun features. You'll also have the chance to enter our weekly What's Up? space trivia contest. You're going to look great in the Planetary Radio T-shirt you win!

—Mat Kaplan,
Planetary Radio Producer

You Say It's Your Birthday . . . Celebrate!

New York City elementary school pals and future astronauts Jan and Luke are aiming for Mars! For their recent birthdays, they didn't ask for toys—they asked their party guests to give a gift to The Planetary Society.

We were delighted! In keeping with the party theme and the birthday boys' wish to explore the Red Planet, we gave each of their classmates a one-year membership in the Society. That way, they, too, can take part in the exciting adventure of space exploration.

This is just one way to celebrate a birthday—or honor a special person or anniversary—while supporting the Society. When you make an honorary gift, we will send the person honored an acknowledgment of your donation, without mention of the amount.

For more information about making an honorary gift, please contact Andrea Carroll at 626-793-5100, extension 214, or *andrea.carroll@planetary.org.*

—Andrea Carroll,
Development Director

Attend Events Around the World!

Did you know that the Society keeps a listing of current events of interest to our members on its website? We list worldwide events, sponsored by The Planetary Society as well as by other groups, and encourage you to check the calendar from time to time to find an event to attend in your area. This list is always being updated, and we encourage you to let us know about similar events in your community by e-mailing *tps.vz@planetary.org*.

We would like to take this opportunity to thank our many volunteers who have helped staff a Society table at some of the past events. If you are interested in becoming a part of the Volunteer Network and joining with other members at a future event, please e-mail Lonny Baker at *tps.lb@planetarysociety.org*. Check for upcoming events in your area on our Events calendar at *http://planetary.org/html/society/calendar.html.*

—Vilia Zmuidzinas,
Events and Volunteer Coordinator

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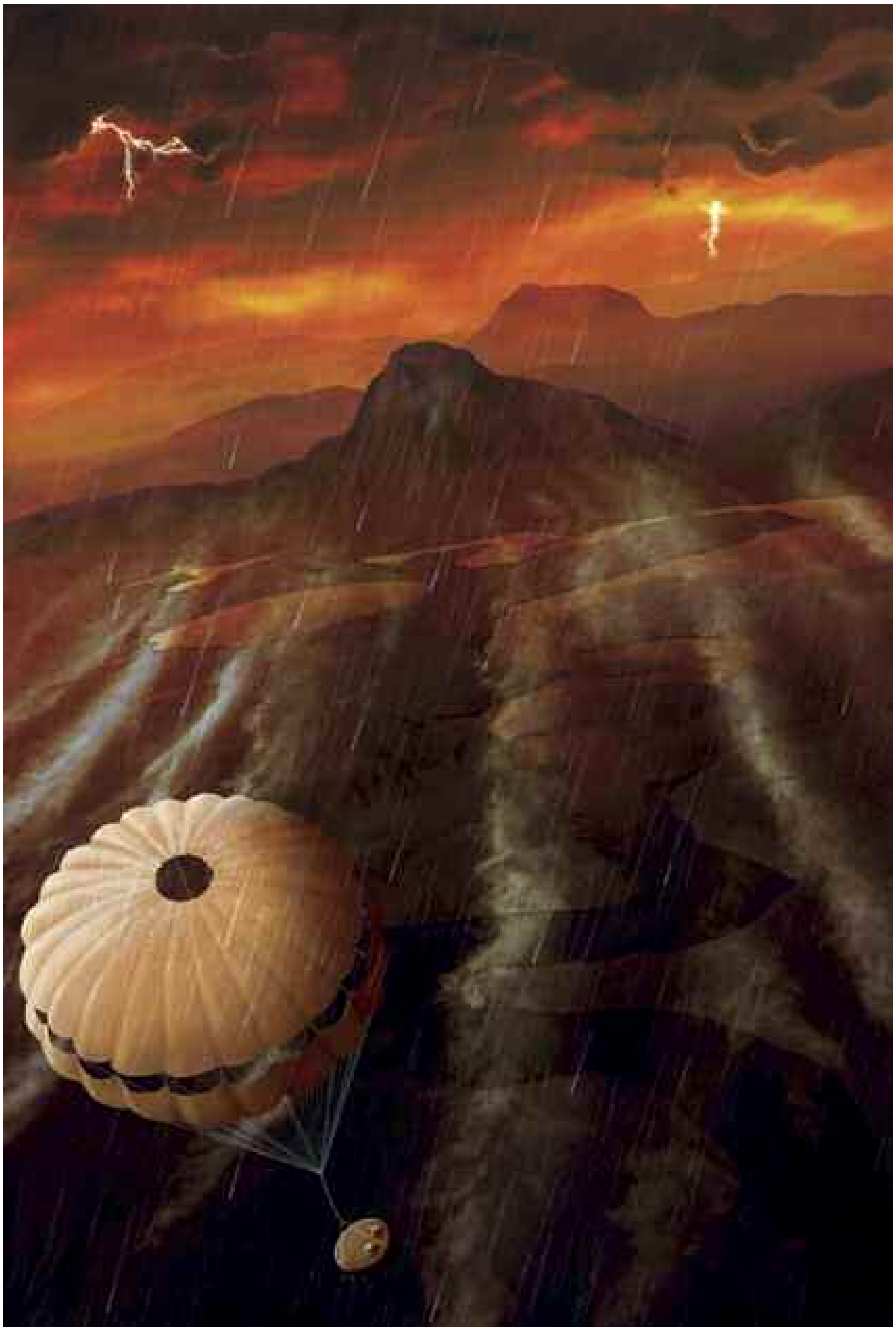

In January 2005, the European Space Agency's *Huygens* probe will become the first spacecraft to land on a world in the outer solar system. And what a world it is! Titan, Saturn's largest moon, is the only satellite in our solar system with an atmosphere—a dense blanket of nitrogen and organic materials that may hold answers to our questions about life's origins on Earth. In "Stormy Descent," *Huygens* floats down to explore a surface that spacecraft—and human eyes—have never seen.

Mark Garlick worked as a professional astronomer for only three years before deciding in 1996 that he'd be happier working as a freelance space artist and writer. Since then, his images have appeared by the hundreds in books, in magazines, and on television. His articles have appeared in many publications, including *New Scientist, Astronomy Now, Scientific American,* and *Modern Astronomer.*

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