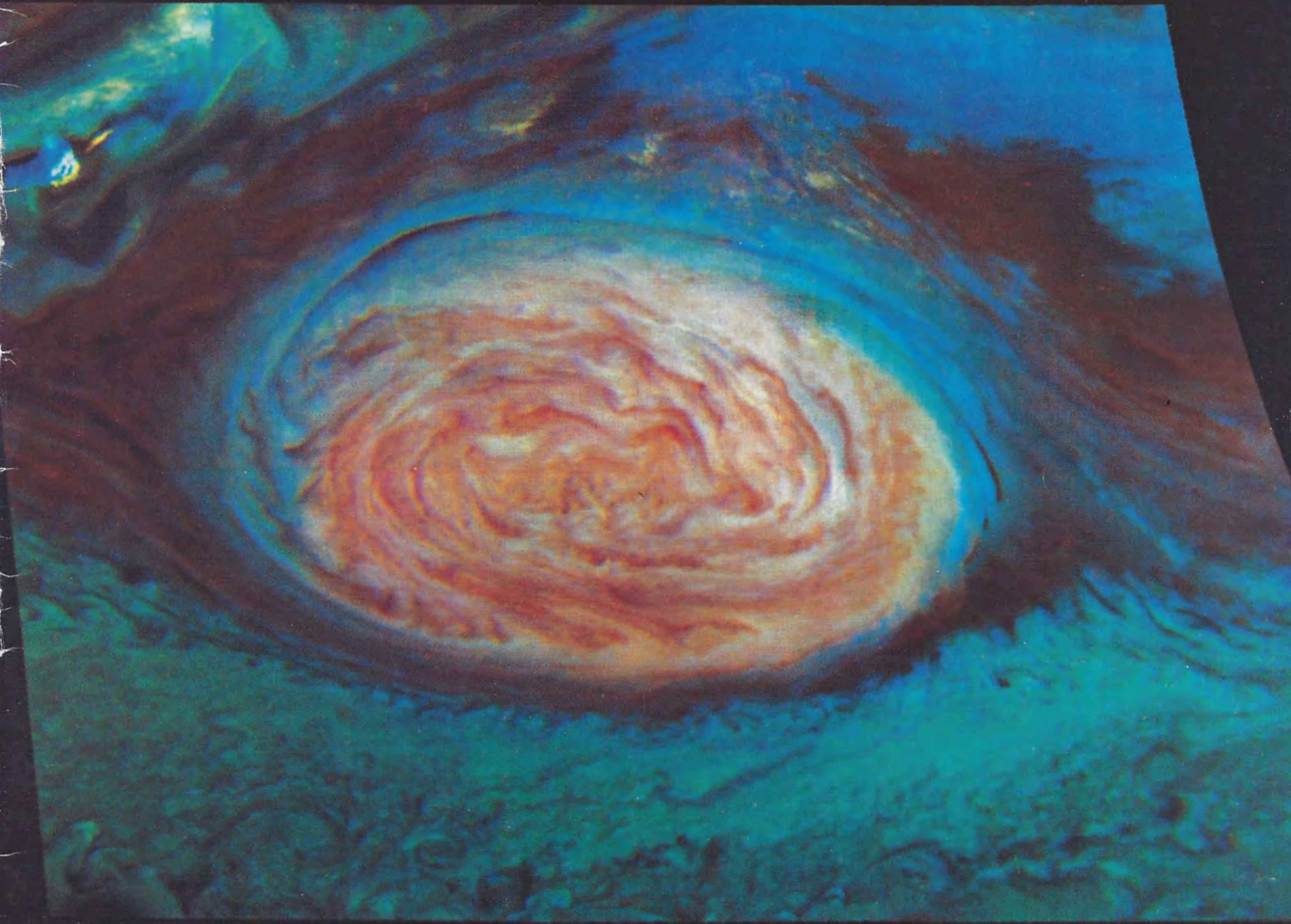
The PLANETARY REPORT

Volume XVI Number 6 November/December 1996



Galileo's Wild Ride

On the Cover:

A familiar jovian feature appears as the Great White Spot in this false-color rendition created from data gathered by the *Galileo* spacecraft. Here the colors indicate cloud heights, not the composition of the particles that give Jupiter's atmosphere its predominant red, white and orange tints. In this image, white indicates high, thick clouds. For example, the white areas near the north edge of the gigantic cyclone are little thunderstorms. In natural light, the Great Red Spot appears red because of a high haze swirling at the top of the storm. So here, it is white. New products such as this are giving scientists new ways of learning about Jupiter.

Image: JPL/NASA

From The Editor

Never in the 16 years The Planetary Society has existed has the public been as excited by a planetary discovery as they are about the possible evidence of ancient life on Mars. Needless to say, we want to bring Society members the best possible coverage of this continuing story. That takes time, so in this issue you won't see a feature on martian life. But with the next issue, we'll begin what we hope will be the most comprehensive coverage among the popular magazines devoted to planetary science.

It is our style to have scientists themselves write their stories for *The Planetary Report*. In the next issue you will hear from Roberta Score, who found meteorite ALH84001, and David Mittlefehldt, who discovered that it had come from Mars. We'll also present excerpts from an exciting conference held soon after the discovery was announced.

Then, in our March/April issue, we'll hear from David McKay, the leader of the team that discovered the traces of possible martian life. McKay is, understandably, too busy to meet our deadline for the next issue, but he's very pleased to be writing his story for our members. So stay close. The best is yet to come.

—Charlene M. Anderson

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The planetary probes of NASA, the Russian Space Agency and the European Space Agency tend to garner most of the media attention, but Japan is slowly and deliberately building an ambitious planetary program. The Japanese have sent spacecraft to comet Halley and the Moon, and now they have their sights on Mars. Planet-B, scheduled for launch in 1998, will investigate Mars' upper atmosphere, a little-explored region that may have much to tell us about the Red Planet.

12 *Galileo's* First Look at Ganymede and Europa

It's been a very long wait, but now the *Galileo* orbiter is relaying its harvest of data back to Earth. We'll be covering the mission regularly as *Galileo* continues its tour among the jovian moons, and here we begin with wonderfully detailed images from the first Ganymede encounter, along with beautiful images of Europa taken "over Ganymede's shoulder" as the spacecraft flew by the largest moon in the solar system. Even better images of Europa will be returned in December, as *Galileo* has its first close encounter with that icy world.

17 A Great Year

Looking back over 1996, Society Executive Director Louis Friedman found a lot to praise NASA for. This special article replaces World Watch in this issue. Our regular political column will return in January/February 1997.

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Members' Dialogue

Altered Probabilities

I disagree with Ernst Mayr's views on the possibility of extraterrestrial civilizations (see the May/June 1996 issue of *The Planetary Report*). On Earth, there has been a demonstrable "ratcheting effect" connected to the one known intelligent, civilization-building species. We have efficiently domesticated, eliminated and transformed other species. We have altered terrain, dammed rivers and generally exerted control over our environment. This gives us a nearly insurmountable advantage over competing species on this planet, and though our foresight is limited and flawed, it still gives us a huge measure of control. I think it would be just as hard to wipe out the seeds of human civilization as it would be to eliminate the ants and cockroaches.

Small groups of humans, the Incas for example, have migrated and built civilizations. Short of the complete extermination of humanity, it is probable that civilization would reemerge in a few thousand years after any disaster. I think that any other species that may have developed with our type of intelligence and inquisitive nature is probably still there waiting, as fascinated as we are.

Mayr's viewpoint is simplistic because it is based too much on probability, ignoring the fact that any species similar to ours will exert a significant control over some of those probabilities. In that way, it *is* an evolutionary advantage for any species to have our sort of intelligence, which has manifested itself in a fairly successful optimizing of our environment to favor humans over any other species. For such a physically degenerate group of primates, we have done amazingly well.

—TERRENCE CHURCHMAN,
Pasadena, California

If we do not search for life beyond Earth, then it is very likely that we will never know if it does or does not exist. Talking about it endlessly gets us nowhere in the end.

—LARRY KLAES,
Arlington, Massachusetts

Privatize!

Instead of continuing to complain about NASA and trying to persuade a bunch of congressmen and women to support programs they probably couldn't care less about, why not take matters into our own hands by establishing a private, commercial space agency? This would take the bureaucrats out of the equation and let the visionaries direct the future of space exploration.

It would seem that the tremendous amount of lobbying resources currently being spent could be better directed at creating a private company that would be responsive to space exploration advocates, researchers and industry, rather than at trying to convince a group of people whose main goal is reelection.

—DONALD BREWER,
College Park, Maryland

SETI Donation

As a 1996 Presidential Scholar, I have been awarded a small grant from the Geraldine R. Dodge Foundation. My first thoughts were of using the money to help purchase a computer. But then I read the letter from Dodge Foundation Director Scott McVay, which urged us to, "Take a long hike, listen to the song of the whale and the call of the loon." Another letter read, "We would like you to be creative in the way you use this award."

I must admit that I'm not sure I deserve the grant, and feel slightly uncomfortable accepting it. As the scholars chattered about what to do with the money, I thought of The Planetary Society and Project BETA. The one thing I most want to hear on the evening news is the bulletin that scientists have finally discovered a message from the stars—incontrovertible evidence that we are not alone in the universe. I will start college this fall, preparing to become an astronomer. Whether I contribute to the Search for Extraterrestrial Intelligence as a private citizen through this gift or as a professional astronomer in later years, I deeply want to assist in this great search.

I've also followed Project Phoenix from its inception as a NASA program to its rebirth as a private program. I commend all involved in the project as selfless pioneers both of science and of the human spirit.

Enclosed is $300, part of the Dodge Grant, for use in the SETI program. In my own small way, I've now contributed to the search, and I deeply hope we will succeed.

—JANE RIGBY,
Seaford, Delaware

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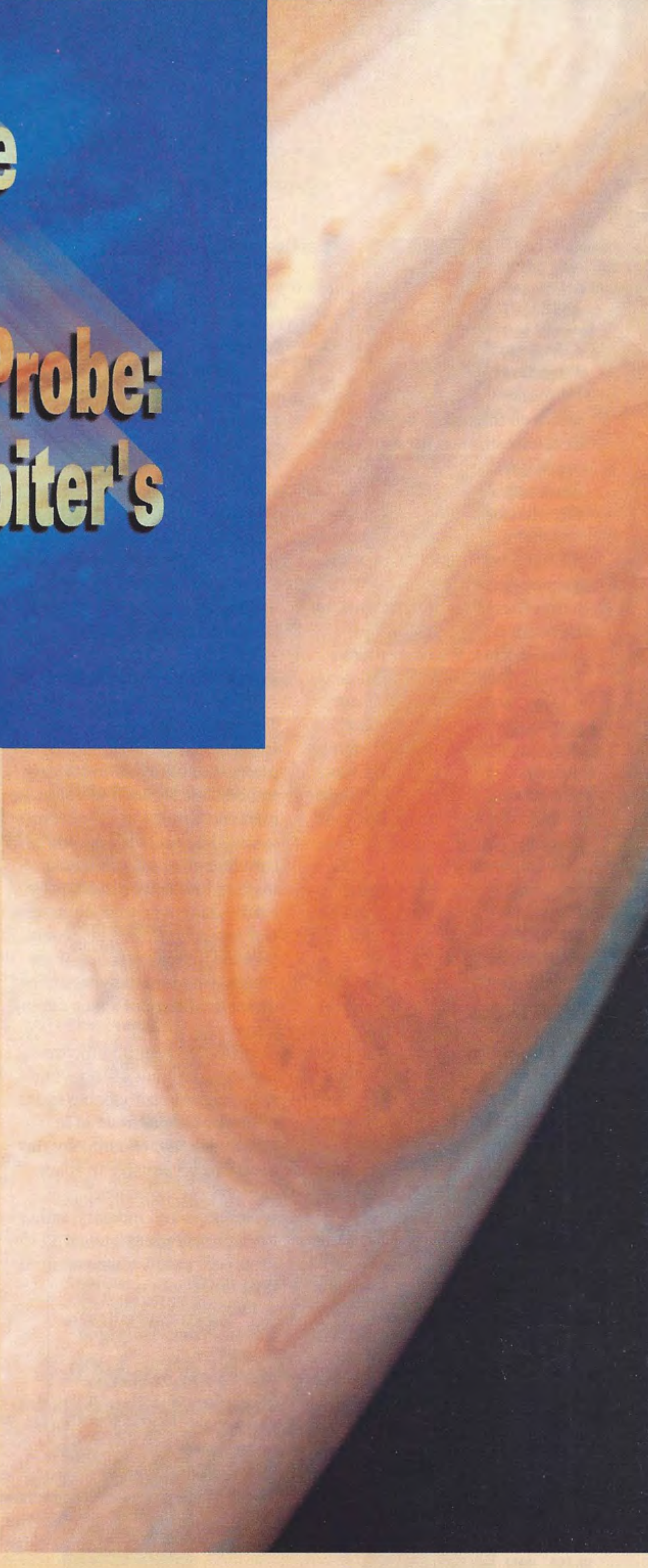
The Wild Ride of the Galileo Probe: Sampling Jupiter's Atmosphere

by Richard E. Young

If you were to identify the most difficult yet most scientifically rewarding planetary missions we could undertake, directly sampling Jupiter's atmosphere would be near the top of the list. Any spacecraft that approaches Jupiter faces extreme hazards, such as intense radiation belts that would fry ordinary electronics, and to sample the atmosphere directly the spacecraft has to survive the most dangerous entry in the solar system. In December of 1995, the *Galileo* probe did just that.

Why Send a Probe to Jupiter?

The purpose of the *Galileo* probe mission was to sample a piece of the solar system that holds fundamental clues to the origin and evolution of all the planets. With over twice the mass of all the other planets combined—more than a thousand Earths could fit inside it—Jupiter is large enough to have kept the materials from which it formed about 4.6 billion years ago, unlike the smaller terrestrial planets, which have lost a good fraction of their lighter elements.



Jupiter's Great Red Spot glares balefully into space in this mosaic of two images from* Galileo. *Humans have been observing this gigantic storm for over 300 years;* Galileo *is giving us our best view yet. *Image: JPL/NASA*

Jupiter also bears the chemical signatures of small bodies, such as comets, that have collided with it. Therefore, Jupiter provides important clues to the processes at work in the solar system.

To develop our models of how planets formed and evolved, we needed compositional and isotopic data on key trace elements. From Earth and spacecraft observations of Jupiter, we expected the abundance, or mixing ratio, of helium (the ratio of the number of helium atoms to the total number of atoms) to be smaller there than it is in the Sun, whereas the mixing ratios of carbon, nitrogen, sulfur and oxygen would be larger than they are in the Sun. The abundances of key noble gases, such as neon, krypton and xenon, were unknown.

Also, at pressures much above 1 bar (sea level surface pressure on Earth), we had no measurements of the structure of Jupiter's atmosphere, and only a few imprecise temperature-and-pressure data points for the uppermost atmosphere. The only way to get these measurements was with a probe. What we knew about the atmosphere's composition indicated that there probably were three cloud layers. We couldn't see the lower two cloud layers, predicted to consist of ammonium hydrosulfide and water, respectively, but we inferred their existence from spectroscopic data and comet Shoemaker-Levy 9 impact studies.

We had major questions about the weather of Jupiter and all the large outer planets. One particularly important question was whether the global pattern of zonal (east–west) winds we'd seen on Jupiter, Saturn, Uranus and Neptune extends deep into their atmospheres or instead is confined to cloud levels. This question has implications for the energy source and driving mechanisms of the winds and could only be addressed by a probe.

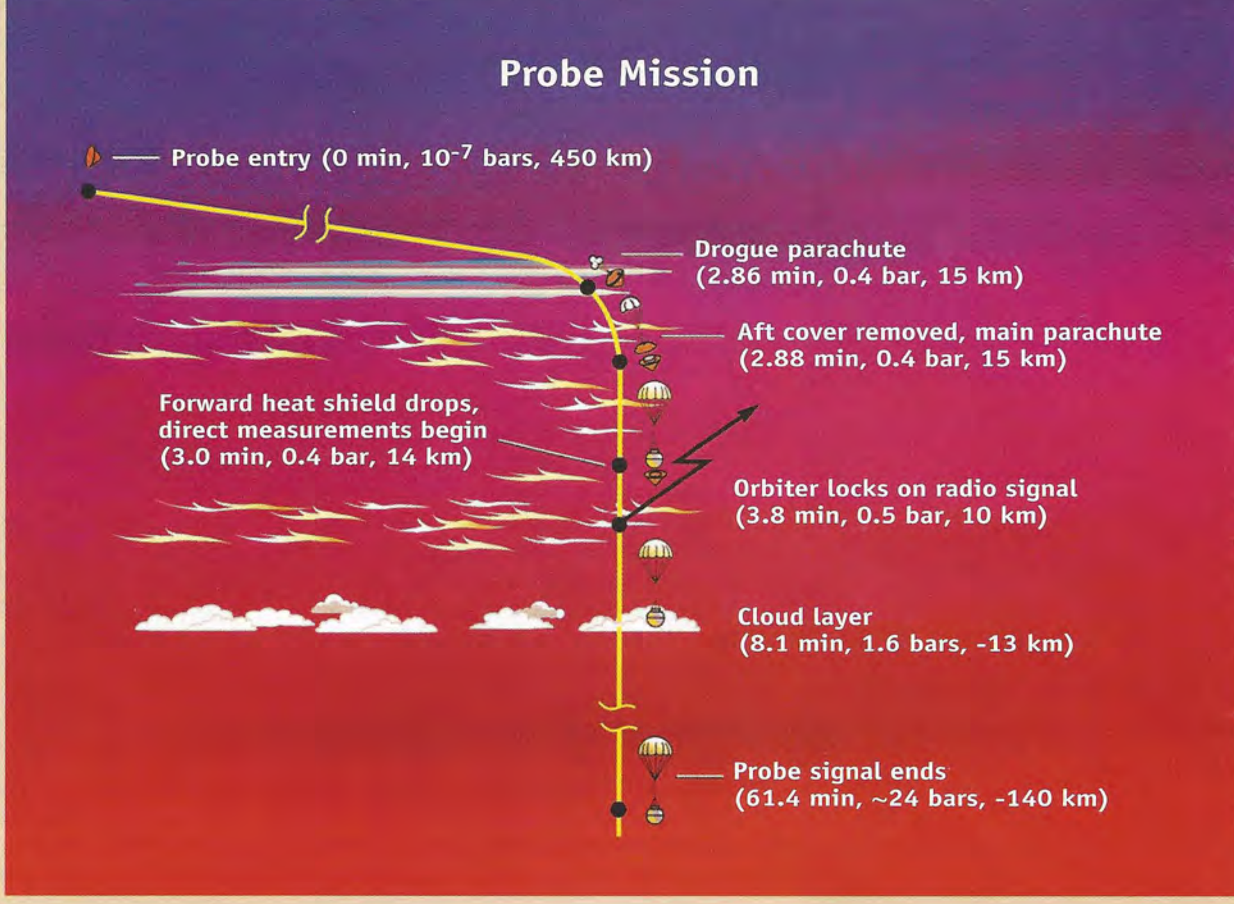
The Probe

Galileo, consisting of two main components, an atmospheric entry probe and a planetary orbiter, was launched on October 18, 1989, on the space shuttle *Atlantis*. After a circuitous route that included a close flyby of Venus and two close flybys of Earth for gravity assists to gain energy, the probe separated from the orbiter on July 12, 1995. At this point, both the orbiter and the probe were about 50 million miles and five months away from arrival at Jupiter. Once the two separated, we could not communicate with the probe nor change its trajectory. On December 7, 1995, both orbiter and probe arrived at Jupiter. The orbiter began a 22-month tour of the jovian system, and at 14:04 Pacific standard time on Earth, the probe plunged into the atmosphere.

To appreciate the achievement of the *Galileo* probe, consider the following items. The probe entered the atmosphere

The Galileo *probe consisted of three main components: the forward heat shield, the aft heat shield and the descent module. The instruments were housed in the descent module.*

Image: JPL/NASA; redrawn by B.S. Smith



The elapsed time from probe entry (defined to be 450 kilometers, or 280 miles, above the 1-bar pressure level) to loss of probe signal near 24 bars was 61.4 minutes. During the high-speed entry, accelerometers measured the deceleration of the probe, from which atmospheric density, and ultimately pressure and temperature, could be derived. The probe began direct measurements 53 seconds (about 0.3 bar) later than planned, due to a malfunction in the wiring between the entry deceleration switches and the probe command processor.

Image: NASA Ames Research Center

at 47.4 kilometers per second (106,000 miles per hour), about 50 times faster than a high-powered rifle bullet. The probe had to enter on a flight path that was 8.5 degrees inclined to the horizontal. An error of 1.5 degrees too shallow, and the probe would have skipped out of the atmosphere; 1.5 degrees too steep, and it would have been destroyed.

Once in the atmosphere, the probe slowed to under 0.5 kilometer per second (1,100 miles per hour) in less than two minutes. During maximum deceleration, the 339-kilogram (746-pound) probe experienced 228 times the acceleration of gravity on Earth, or 228 g, and "weighed" as much as an empty DC-10 jumbo jet airplane. Due to the high-speed entry, an atmospheric shock layer was set up about an inch from the probe's nose. The temperature in the shock layer reached 14,000 degrees Celsius (25,000 degrees Fahrenheit), about 2.5 times the surface temperature of the Sun. The probe survived because of its protective heat shield, which was a carbon phenolic material. About two-thirds of the shield was ablated away during entry.

What the Probe Found Out

What did the *Galileo* probe learn about Jupiter? First, the probe found that Jupiter's main constituents, hydrogen and helium (the two most abundant elements in the universe), are very nearly in the same proportion as they were in the Sun when it formed. Jupiter, by mass, consists of nearly 75 percent hydrogen and 24 percent helium, compared to about 28 percent helium for the Sun at the time of its formation.

This picture of Jupiter is significantly different from our earlier one. Estimates from the 1979 *Voyager* flyby indicated that the helium mass fraction was 18 percent, significantly less than the 24 percent measured by the probe. Remote measurements of helium are difficult to make, which illustrates the advantages of direct sampling. Saturn has in its atmosphere only about a quarter of the helium mass fraction that Jupiter has, implying that Jupiter and Saturn have evolved along different paths.

Although the material other than hydrogen and helium that makes up Jupiter is only a very small fraction of the total, it provides important clues as to how the planet formed, and what processes have since affected it. By comparing their abundances in the Sun, we can use such heavier elements as carbon and oxygen, and noble gases such as neon and xenon, to trace the evolution of Jupiter and compare it with the inner planets. *Galileo* found that carbon and sulfur have greater abundances relative to hydrogen on Jupiter than they have in the Sun, by about a factor of 2 to 3 (we've not yet determined the abundance of nitrogen measured by the probe). However, oxygen, in the form of water since Jupiter is much cooler than the Sun, seems to be scarce, at least where the probe entered. This is very different from what we expected. We thought the probe would encounter thick water ice clouds, and water would be an important atmospheric constituent, as it is on Earth. Jupiter's dryness was certainly a great surprise.

The greater abundances of carbon and other heavier elements on Jupiter compared to the Sun imply that comets and other small bodies have collided with Jupiter and deposited extra material. However, it is hard to understand why these impacts would not also have brought in water (and hence oxygen). Similar impacts may have played a role for Earth, bringing in water that is now in our oceans and gases that are now in our atmosphere. Hence, understanding the role of small impacting bodies is an important topic, and the information the probe gave us may force new ways of thinking about that role.

The probe also searched for organic compounds containing carbon, hydrogen and other elements. Some organic compounds, of course, play important roles in biological processes on Earth. The probe saw only extremely small amounts of complex organic compounds, implying that such compounds are rare on Jupiter, and the chances of biological processes are very remote.

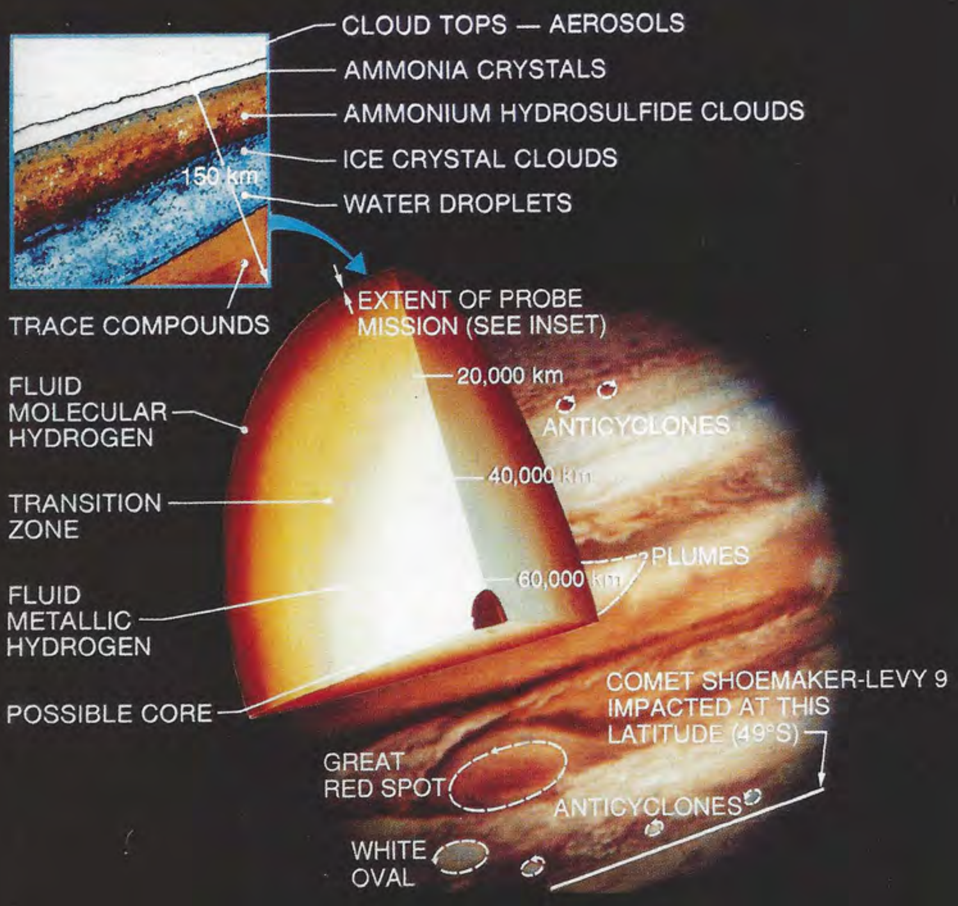
Winds and Weather

One of the probe's main objectives was to measure the winds on Jupiter. From pictures taken by spacecraft and by Earth-based telescopes, we knew that at cloud levels jovian winds blew mostly in the east–west direction and reached speeds of over 100 meters per second (225 miles per hour). Recent measurements from HST indicated that there were narrow jets at the probe entry latitude, moving in the same direction Jupiter rotates and reaching speeds of about 150 to 170 meters per second (335 to 380 miles per hour). We didn't know if these winds extended to significant depths below the clouds.

The probe encountered winds over 180 meters per second (400 miles per hour), and showed that the winds extend deep below the visible clouds on Jupiter. For reference, the winds in a tornado are typically between 300 and 500 kilometers (200 and 300 miles) per hour, and the highest sustained winds ever recorded in a hurricane were 123 kilometers (198 miles) per hour. We don't know exactly how the winds are produced, but the probe provided evidence that energy escaping from Jupiter's very hot interior is the ultimate energy source. This is very different from weather on Earth, which is entirely driven by energy from the Sun.

The probe also measured the way in which temperature and pressure are related. They increase with depth. The probe radioed signals to the orbiter until it reached a depth where the pressure was about 24 times sea level surface pressure on Earth (24 bars). The temperature at that point was about 150 degrees Celsius (300 degrees Fahrenheit). At the point where the probe first started taking direct measurements, the pressure was about 0.4 bar, and the temperature was a chilly minus 140 degrees Celsius (minus 220 degrees Fahrenheit). In the upper atmosphere, accelerometers determined atmospheric density from the deceleration of the probe, from which we could deduce temperature and pressure. We found that the atmosphere higher than about 300 kilometers (180 miles) above the 1-bar pressure level is hundreds of degrees hotter than expected, reaching temperatures exceeding 900 degrees

(continued on page 9)



Our picture of Jupiter prior to the Galileo *mission. Jupiter is thought to contain a core of heavy elements, such as silicon and iron, which make up the bulk composition of the inner planets. Surrounding the inner core is a layer of metallic hydrogen (hydrogen enormously compressed) extending to roughly three-quarters the radius of Jupiter. Metallic hydrogen is electrically conducting, and fluid motions in this layer generate Jupiter's magnetic field. Above the metallic region are fluid hydrogen and helium, becoming gases near the outer regions. Although the* Galileo *probe penetrated a very small distance into Jupiter, its findings have implications for the whole planet.*

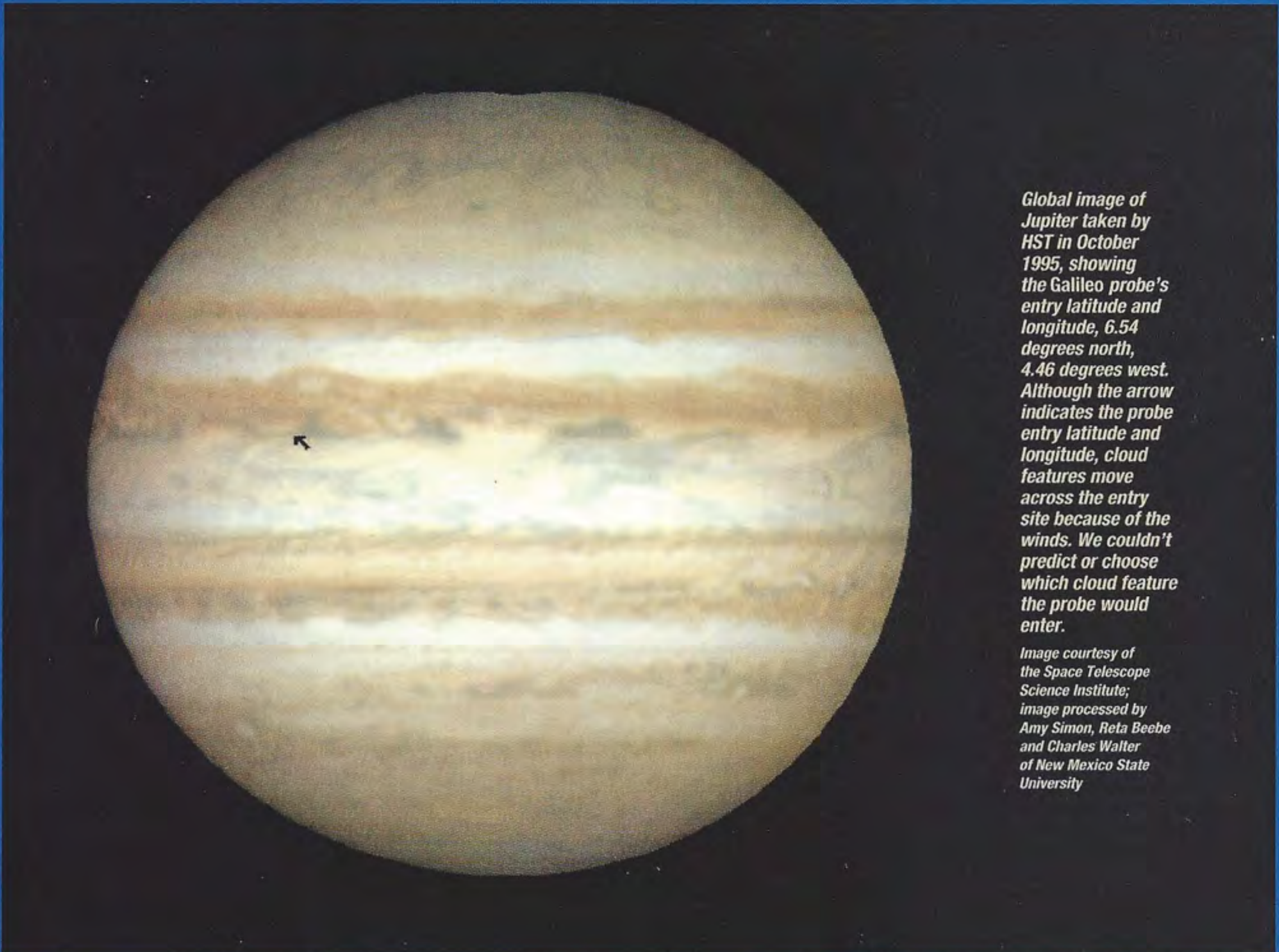
Image: JPL/NASA

The Entry Site: A Representative Sampling?

Our interpretation of the probe results depends on our understanding of how representative the entry site is of the planet as a whole. Technical problems with the tape recorder on board the *Galileo* orbiter forced us to cancel planned images of the probe entry site. The global image of Jupiter taken by the Hubble Space Telescope (HST) in October 1995 (below) indicates the probe entry latitude and longitude. After October, Jupiter was too close to the Sun as viewed from Earth for HST to image the planet.

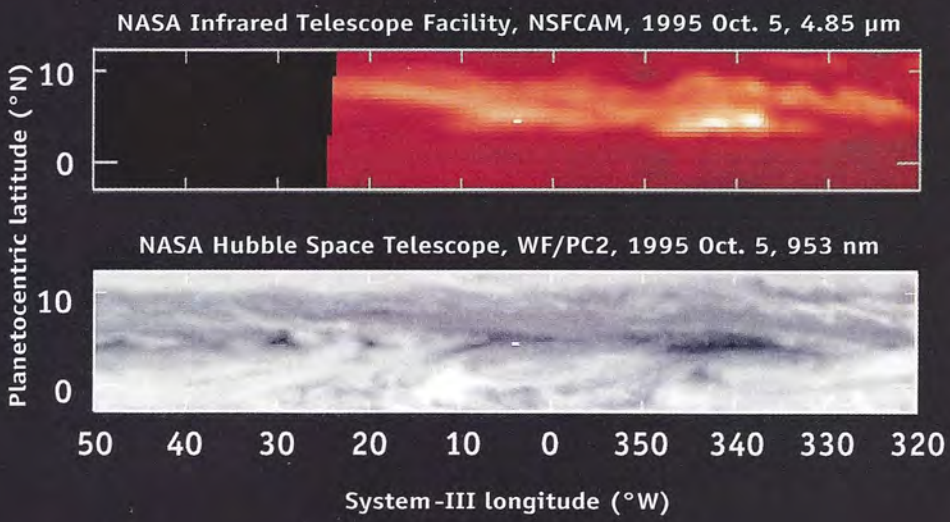
You can compare an HST image from October with an infrared false-color image taken from the Infrared Telescope Facility at nearly the same time (page 9). The cloud patterns near the white spot in the picture are the ones at the probe entry site on December 7. The probe entered near the southern boundary of what is known as a 5-micron hot spot, so called because it is bright near the 5-micron part of the infrared spectrum. Such hot spots cover only about 15 percent of the surface near the equator and are thought to be clearings in the clouds.

To what extent did the probe entry location influence the probe results? That depends on what results are being discussed. Many composition and wind measurements were made deep in the atmosphere, well below the condensation levels of any clouds. Below cloud levels, the atmosphere should be well mixed. If so, the specific spot where the probe entered should not be a factor. However, there could be compositional differences between the belts and zones (the dark and light bands, respectively, oriented east–west). On the other hand, there is little doubt that the characteristics of clouds could be affected by the entry location, and that is apparently the case. The *Galileo* orbiter should help us assess the global versus local nature of the probe results. —*Richard E. Young*



Global image of Jupiter taken by HST in October 1995, showing the Galileo *probe's entry latitude and longitude, 6.54 degrees north, 4.46 degrees west. Although the arrow indicates the probe entry latitude and longitude, cloud features move across the entry site because of the winds. We couldn't predict or choose which cloud feature the probe would enter.*

Image courtesy of the Space Telescope Science Institute; image processed by Amy Simon, Reta Beebe and Charles Walter of New Mexico State University



Cylindrical Maps of Jupiter: 3°S - 12°N

Extrapolated from 1995 Oct. 5 to Dec. 7, Using Eastward Wind Speed = 103 m/s

NASA Infrared Telescope Facility, NSFCAM, 1995 Oct. 5, 4.85 μm

NASA Hubble Space Telescope, WF/PC2, 1995 Oct. 5, 953 nm

Cloud features into which the* Galileo *probe entered. At bottom is an HST image taken in October 1995. The small white line indicates the probe entry site and the cloud feature the probe entered. The false-color Infrared Telescope Facility (IRTF) infrared image at top, taken by Glenn Orton and colleagues, shows that this region is bright in the thermal infrared, and so represents a local clearing in the clouds through which radiation from the deeper atmosphere is escaping. These images and later IRTF images taken in November and December—one within an hour of the probe's entry—enabled the identification of the cloud into which the probe descended.

(continued from page 7)

Celsius (1,650 degrees Fahrenheit).

Even through a small telescope, we can see clouds on Jupiter. The top clouds are ammonia ice particles, mixed with some other compound that colors the clouds. We expected to find two lower cloud layers, the middle one of ammonium hydrosulfide and the lowest one of water ice particles. But, as we learned from Earth-based observations, the probe entered a region that was relatively clear. It started direct measurements near the bottom of the top cloud layer, and by measuring how sunlight diminished as it passed through, it detected the mostly ammonia ice particles. The probe also detected a second cloud, probably made up of ammonium hydrosulfide ice particles. This cloud was very tenuous by Earth standards, and visibility within it was about a mile. But below this, in contrast to our expectations, we detected no thick water clouds. This is consistent with the scarcity of water vapor in the atmosphere at the probe entry site.

In 1979, both *Voyagers* detected lightning as they took pictures of Jupiter's nightside. Most of this lightning occurred near 45 to 50 degrees north latitude. The *Galileo* probe was equipped with optical sensors to detect nearby lightning flashes, but the probe did not detect any lightning optically. It did pick up radio signals emitted by faraway lightning bolts. It seems that Jupiter has less frequent lightning than Earth on a per-unit-area basis, but individual lightning bolts are about 10 times more energetic than on Earth.

Before it hit the atmosphere, the probe measured high-energy charged particles trapped in Jupiter's magnetic field. These radiation belts are analogous to the Van Allen belts above Earth's atmosphere. The probe discovered new radiation belts of helium and heavier ions that extend to within 0.4 jovian radius of the cloud tops.

What was the ultimate fate of the *Galileo* probe? See the article by Lunine and Young in the November/December 1995 issue of *The Planetary Report*.

The Tasks Remaining

Although all the *Galileo* probe data have been returned to Earth, it will take some time, perhaps years, before we understand what they imply about Jupiter and the solar system. In many instances new questions have been raised. This, of course, is how planetary exploration works. New information changes old ways of thinking and raises new questions to explore. In this way our overall understanding of the solar system increases.

The *Galileo* orbiter will return information about Jupiter, its four large moons, and Jupiter's magnetic field until December 1997. The first close encounter with Ganymede, the largest moon in the solar system, occurred on June 27, 1996. The first pictures were released in mid-July (see page 12) and showed remarkable features. Who knows what wonderful surprises await us from the rest of the mission?

Richard E. Young is a research scientist in the Space Science Division at NASA Ames Research Center. He has served as the Galileo *probe project scientist since 1988.*

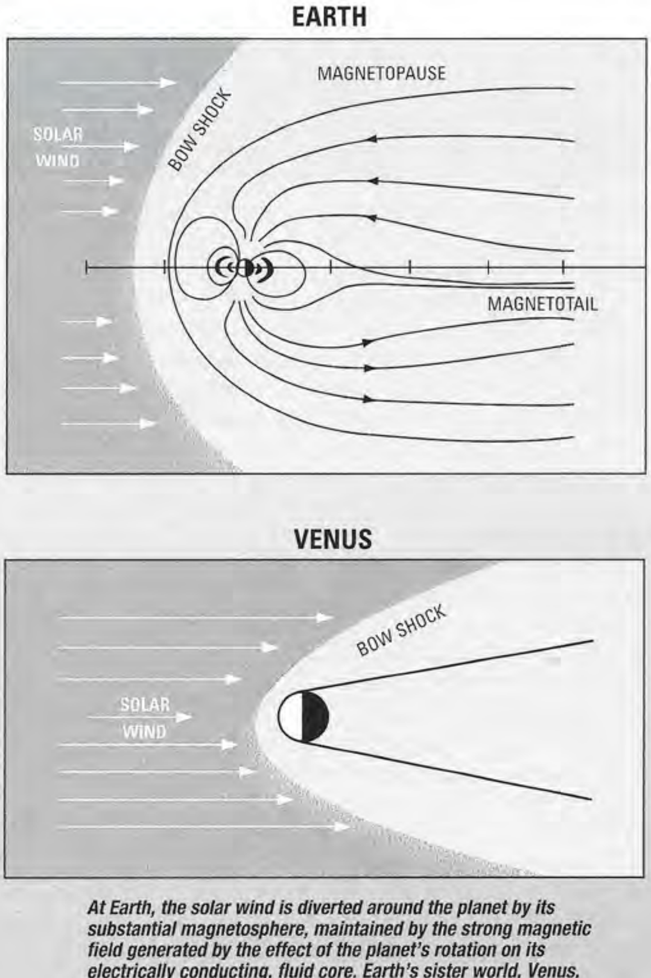
AIMING FOR THE RED PLANET:

by Tatsundo Yamamoto and Koichiro Tsuruda

In August 1998, Planet-B—Japan's first interplanetary spacecraft—will begin its journey to Mars. Scheduled to launch from the Kagoshima Space Center aboard a new launch vehicle called the M-5, the 258-kilogram (569-pound) spacecraft will begin orbiting Mars in October 1999. It will collect data for one martian year (about two Earth years) in an attempt to solve a particularly perplexing puzzle.

The Puzzle

As its thermonuclear fires burn, the Sun emits a stream of ionized particles that we call the solar wind. This so-called wind fills the heliosphere, that region of space defined by the Sun's magnetic influence. At Earth and at all the large outer planets, the solar wind slows and is diverted around these obstacles by their own substantial magnetospheres. Within these teardrop-shaped pockets of space, the rotating planets generate magnetic fields. The solar wind collides with a planet's magnetosphere at a boundary called the bow shock. There it slows and flows around the planet's region of influence, much as water flows around a rock in a stream.



At Earth, the solar wind is diverted around the planet by its substantial magnetosphere, maintained by the strong magnetic field generated by the effect of the planet's rotation on its electrically conducting, fluid core. Earth's sister world, Venus, rotates too slowly to generate a large magnetosphere, but its ionosphere is substantial enough to divert the solar wind. The situation at Mars appears to be more similar to that at Venus than to that at Earth, but Planet-B should enable us to pin it down.

Charts: B.S. Smith, based on material from The New Solar System, *Cambridge University Press*

Small worlds like Earth's Moon may possess faint magnetic fields, but they lack the fluid, electrically conducting cores needed to generate substantial magnetospheres. Other rocky worlds, like Mercury and Venus, may have fluid cores, but they rotate too slowly to generate large spheres of influence. Mars rotates in 24.6 hours, a period nearly identical to Earth's day. But with only half Earth's radius, it was once thought too small to have retained enough heat from its formation to maintain a fluid core.

Spacecraft have given us hints that Mars possesses a magnetic field, but so far there's been nothing conclusive. Still, something slows the solar wind as it approaches Mars. The region of the upper atmosphere composed of ionized, electrically conducting gases called the ionosphere may account for some of the slowing. But the amount of slowing—as measured by *Viking* and *Phobos 2*—is larger than we would expect from the effects of the ionosphere. So we have a mystery to solve: Could Mars possess an intrinsic magnetic field?

Examining the Ionosphere

To solve this mystery, we need to know more about the composition and structure of Mars' ionosphere. Planet-B is equipped to give us this much-needed information. For example, to estimate the ionosphere's strength against the impinging solar wind, we need to know the temperature of its electrons—the higher the temperature, the higher the pressure of the ionosphere and therefore the greater its strength.

When the solar wind first approaches Mars, the wind encounters hot atoms in the upper reaches of the ionosphere. Some of these atoms are ionized by interaction with the solar wind's ions or by ultraviolet radiation from the Sun. These ions are then carried away with the solar wind.

In 1988 and 1989, *Phobos 2* detected these escaping ions; they leave the planet's atmosphere, forming a "tail" that trails away from the nightside of the planet. The total of the mass and energy carried away by the escaping ions is so great that if the escape occurs continuously there will be a significant effect on the atmosphere's evolution. Scientists believe that this may be one way water leaves the planet—it may be broken down into hydrogen and oxygen ions and then taken away by the solar wind. Planet-B's instruments will measure the ratio of hydrogen to its heavy isotope deuterium in Mars' atmosphere; we can then compare that ratio with the ratio for other planets (like Earth) to get a clearer picture of how hydrogen atoms escape, and thus how water escapes.

If the orbiter's instruments find that the solar wind impinges directly against Mars' ionosphere, that would tell us that the magnetic field may be like that of Venus, which is very weak. On the other hand, if it is anything like Earth's, then it would be able to sustain pressure from the impinging solar wind's dynamic pressure. (See the diagram on page 10.)

If there is an intrinsic magnetic field, weak or strong, that would indicate that there is some dynamo action in the martian core—that is, some physical process may be generating a magnetic field. Could the martian core possibly still be partially liquid, like Earth's? And could the planet still be warm on the inside today?

Dusty Rings

Planet-B will be examining many aspects of Mars' atmosphere as it circles that dusty planet, where huge dust storms periodically rage across the surface. The two small satellites of Mars, Phobos and Deimos, could be a dust source high above it, as meteorites smack into them, pulverizing their surfaces. Perhaps the dust that is raised forms rings similar to those around Saturn. Planet-B will measure the dust around Mars and help us determine if the planet does indeed have thin, faint rings.

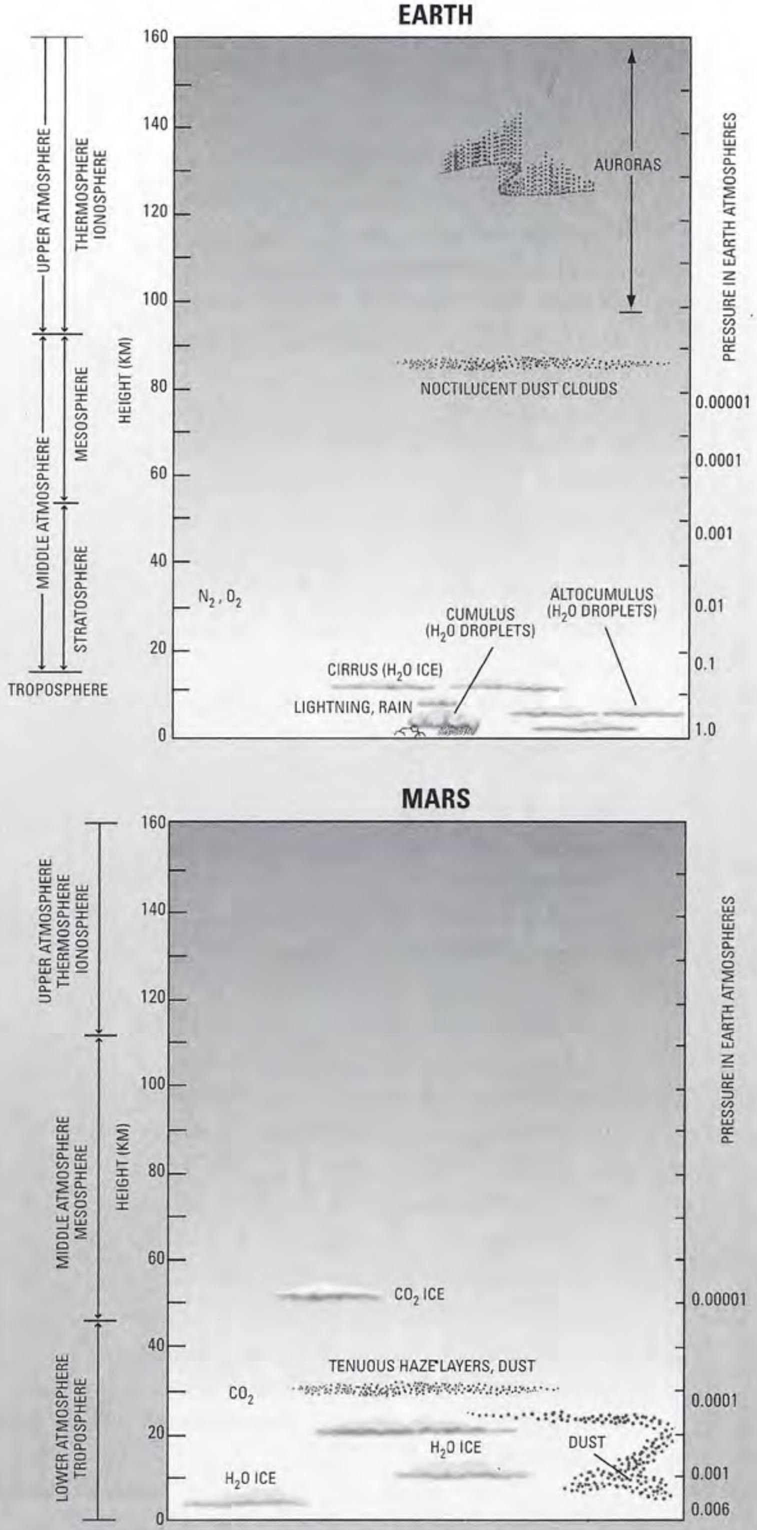
The Planet-B camera will capture numerous images of Mars as it monitors meteorological activities in the lower atmosphere. Consecutive global images will give us some basic information on cloud distribution, polar haze, the dust storms, and the growth and decay of polar ice. We'll also get a look at the planet's surface. By comparing Planet-B images with those from *Viking,* we hope to get a better understanding of weathering effects on Mars.

Planet-B's orbit intersects those of Phobos and Deimos. The camera will also take close-up images of these satellites as the spacecraft encounters them.

Although studying Mars' atmosphere might not be as exciting as landing on the planet, Planet-B will still teach us a great deal about Mars. We will get answers to questions that older missions to the planet have raised, and, in turn, we'll uncover new questions for future explorers.

Tatsundo Yamamoto and Koichiro Tsuruda are scientists at the Institute of Space and Astronautical Science in Kanagawa, Japan. Both are working on the Planet-B mission.

A version of this article appeared in the third quarter 1996 issue of *The Mars Underground News*.



An ionosphere is part of the uppermost atmosphere of a planet. In that region, ionized, electrically conducting gases are abundant, and they are able to divert the solar wind so that it flows around the planet. Beneath the ionosphere lie the more familiar parts of an atmosphere, such as clouds of water, dust and, on Mars, carbon dioxide.

Charts: B.S. Smith, based on material from Moons and Planets, *Wadsworth Publishing*

Galileo's *First Look at*

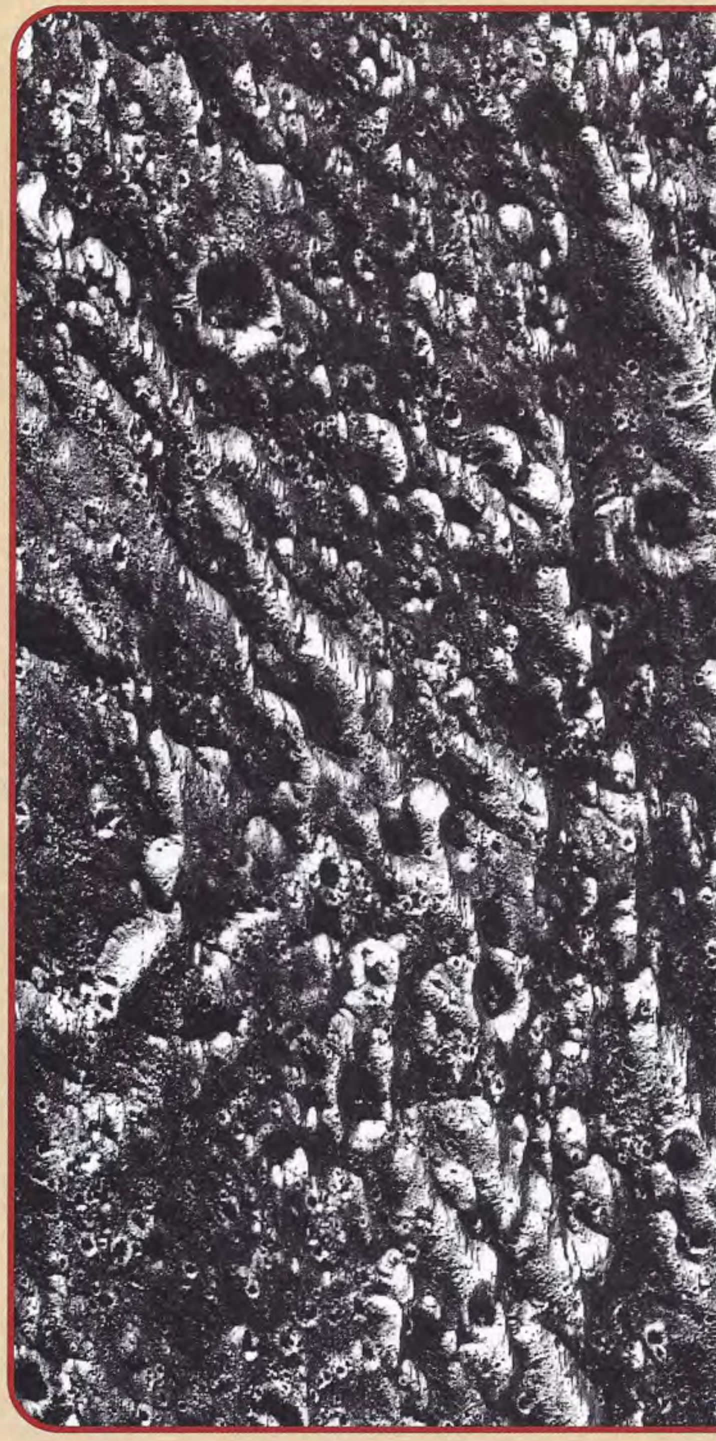
GANYMEDE

Sometimes you think you really know a moon—then you get closer, and you find you don't really know it at all. That's the situation for *Galileo* project scientists, who had prepared for the encounter with Ganymede by studying *Voyager* images taken 17 years earlier. They found that their assumptions about the third large moon out from Jupiter would have to be greatly revised.

The biggest surprise was the discovery that Ganymede possesses a substantial magnetic field. Since the moon is made mostly of water ice and rock, it probably lacks a molten metal core like the one that generates Earth's magnetic field. Many scientists simply assumed that *Galileo*'s magnetometer and plasma wave instrument would pick up nothing as the spacecraft flew by the moon. But the instruments did pick something up—a magnetic field about one-fortieth the size of Earth's, quite strong for a body 5,260 kilometers (3,260 miles) in diameter. What could generate such a field on an object like Ganymede? Some scientists have speculated that the field is perhaps generated by convection within a salty, subsurface ocean. This intriguing possibility will need to be confirmed by further observations.

Then, there's Ganymede's wrinkled face. From *Voyager* images, scientists had surmised that the dark areas were ancient regions of muddy ice, and the bright areas were smoother, younger regions of cleaner ice. But with images showing between 70 and 140 times the detail of its predecessor's, the picture of the moon as seen by *Galileo* is much more complex. As you'll see in these images, Ganymede is a very strange place.

These images are from the spacecraft's first close encounter with Ganymede on June 27, 1996. The second occurred on September 6, and, as I write this, the data are still coming back. There will soon be more to tell about Ganymede, the largest moon in the solar system.
—Charlene M. Anderson



The large, dark region called Galileo Regio is one of the most prominent features on Ga
during the Galileo *spacecraft's first encounter with this moon. From the* Voyager *image*
dark area was ancient terrain, probably heavily cratered from collisions with asteroids
They were right about that; like many other ancient surfaces, it is pocked with impact s
At first glance, mission scientists thought this image was upside down: The sunlight is
58 degrees above the horizon, yet many of the features appear lightest on the side faci
were coming from the opposite direction. It looks as though the dark and light areas ar
indicating that meteorites have left behind dark materials to shade the icy crust.

At the left edge of the image is half of a 19-kilometer-wide (12-mile) crater. The fur
right is part of a concentric ring around a large impact basin. The nearly vertical furrow
radiating from the basin.

This image covers an area 46 by 64 kilometers (29 by 40 miles), with details as sma
visible. It was taken on June 27, while the spacecraft was 7,563 kilometers (4,700 mile

Ganymede *and* Europa

mede and was targeted for imaging
scientists had deduced that this
nd comets over billions of years.
ars. But it is also—well, strange.
oming from the lower left, about
away from the Sun, as if the light
intrinsic to the surface, perhaps

w running from top left to lower
hrough the center may be a crack

as 80 meters (260 feet) across
from the moon.

"Fractures within fractures" describes the terrain of Uruk Sulcus, a bright region bordering the dark Galileo Regio on Ganymede. Terrain of this type covers about half of the moon. Judging from the number of craters, the area in the upper right part of the image is older than the area in the lower left, whose fractures run nearly perpendicular to those of the older terrain. In the upper left, on the boundary between the two areas, is a crater that has been half-consumed by the younger terrain. The large circular feature in the younger terrain is an impact crater; the dark material to the right of the crater may be ejecta thrown out by the collision.

At the time this image was taken, the Sun was almost directly overhead, so the dark and light detail seen in the fractures is due to differences between the types of materials exposed on the surface, and not to sunlit and shadowed features.

This image covers an area 55 by 35 kilometers (34 by 22 miles), and the smallest features visible are 74 meters (about 240 feet) across. Galileo *took the image from a range of 7,448 kilometers (4,618 miles).*

Images: JPL/NASA

Please turn the page to see the images of Europa. →

EUROPA

Since it would have fallen on the day after the press conference announcing the discovery of possible evidence of ancient life on Mars, NASA postponed the science briefing releasing *Galileo*'s new images of Europa. The Jet Propulsion Laboratory and the space agency believed that the Galilean moon would be lost in the flood of publicity that followed the martian finding. It was probably a wise move, for the complex hypothetical arguments that make Europa the second best place off Earth to look for signs of life could not compete with what might be images of fossil bacteria.

Still, for those who follow planetary exploration, Europa can hold its own. In 1979, the *Voyager* spacecraft returned images of a world about the size of Earth's Moon with an eerily smooth but fractured surface. The dearth of impact craters indicated that the satellite's face was extremely young and was continually being resurfaced by some active geologic process. In an effort to understand that process, scientists began to speculate that a global ocean of liquid water might lie under a thin crust. Tidal forces among Jupiter and the other large jovian moons might keep the water from freezing and occasionally cause it to break through the frozen crust and cover up signs of impacts.

Where there's liquid water, there is the potential for life. And if the ocean models are correct, there may be more liquid water available today on Europa than on Mars.

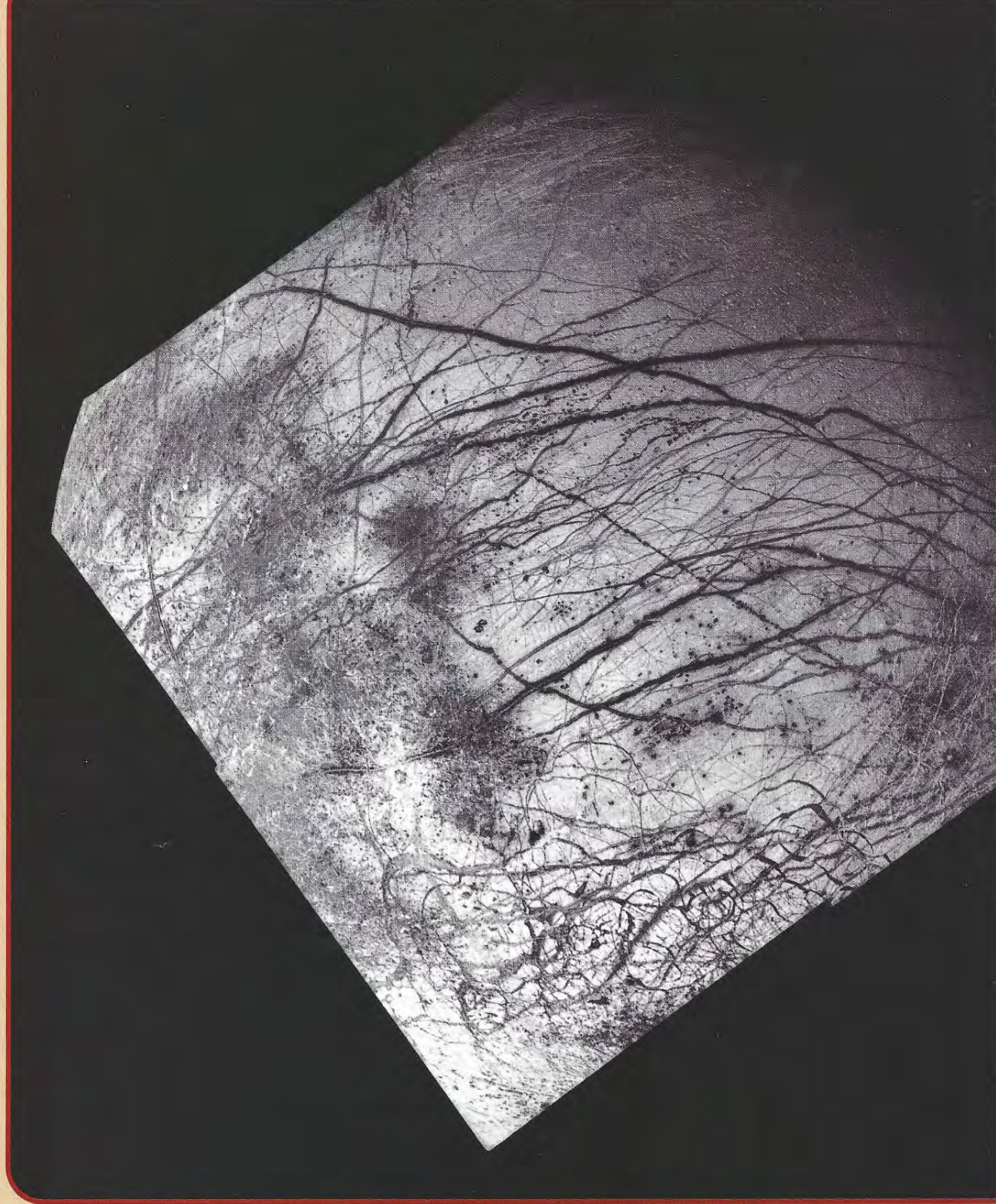
This is what makes Europa so exciting. But as yet, there is not enough evidence to determine what lies beneath that smooth, cracked crust. At the science briefing, NASA felt compelled to release a cautionary statement from Administrator Dan Goldin. He said, "We're not going to jump the gun. These pictures do not prove the existence of liquid water on Europa, and the higher-resolution pictures to come may not prove it. A few days ago, I greeted the possibility of ancient microbial life on Mars with skeptical optimism, and invited further scientific examination and debate. I greet the new pictures of Europa in the same light."

These images of Europa were taken, in a manner of speaking, over Ganymede's shoulder during *Galileo*'s close flyby of the larger moon, while the spacecraft was 156,000 kilometers (about 96,700 miles) away. On December 19, 1996, *Galileo* will make its first close encounter with Europa. Soon we will know more about this moon of such intriguing possibilities. — *CMA*

This close-up shows the highly fractured area at the bottom of the mosaic at right. Here you can see details of the complex mix of straight lines, curves and wedges that mark Europa's surface. Between the cracks are plates of ice. Some of the individual plates appear to have twisted around after they formed, slid across a "lubricating zone" and settled in new locations. This area resembles ice floes commonly seen in Earth's arctic regions.

Galileo *scientists have been particularly intrigued by the "triple bands" of dark-bright-dark features stretching for hundreds of kilometers across Europa. They speculate that icy eruptions from beneath the crust pick up dark silicates and deposit them on the surface. Later, purer water follows, depositing the bright central lines.*

This image of Europa's equatorial region covers an area about 360 by 770 kilometers (220 by 480 miles), and the smallest features visible are about 1.6 kilometers (1 mile) across.



Europa's fractured face is dramatically displayed in this mosaic of four images taken on June 27. The fractures may be created as gas and rocky slush from the interior erupt through the crust. Scientists speculate that liquid water or "warm ice" may exist just below the surface. Many of the dark cracks are over 1,600 kilometers (1,000 miles) long, longer than the famous San Andreas fault in California. At the bottom of the mosaic is a highly fractured region where the crust has broken into slabs, some of them 30 kilometers (18.5 miles) across.

If you look carefully along the sunset terminator (the boundary between the day and night sides of the moon), you'll see dozens of shallow craters. Some areas seem free of craters, indicating that they were recently resurfaced. Some of the dark spots near the center of the image may be the scars of water geysers, which sometimes erupt through the icy surface, carrying dark, muddy material with them.

The area seen here is about as wide as the United States west of the Mississippi River. The north pole is near the top of the image, and the Sun is illuminating the moon from the left. *Images: JPL/NASA*

News and Reviews

by Clark R. Chapman

The weekly magazine *Science* made headline news worldwide when it published research on meteorite ALH84001 suggesting past life on Mars. Yet the cover of the famous August 16th issue says nothing about the Mars rock, instead touting a section of reports on thin films.

Science, published by the American Association for the Advancement of Science (AAAS), treats research on subjects from physics to social science but is especially heavy on biology. Some important Earth and space science papers appear in it, and staff-written commentaries and meeting summaries keep general readers up to date on broad planetary topics.

The 175-page August 16th issue has far more of planetary interest than just the seven-page article by David McKay et al. on ALH84001. There are technical reports about Jupiter, near-Earth asteroids and Edgeworth-Kuiper belt comets. There is even a brief movie review (illustrated by a comet collision on the young Earth) of the new IMAX film *Cosmic Voyage,* which features a powers-of-10 zoom from the universe down to subatomic scale.

Old *Science*, New *Science*

A decade ago, *Science* still adhered to a traditional format. There were a few longish technical research articles plus a couple of dozen shorter technical reports. In the front of each issue was an editorial, some letters to the editor, plus a few staff-written summaries of meetings or committee reports. Finally, there were staff-written commentaries on the politics and business of science, topics that dominate annual AAAS meetings. And that was that.

Science's competitor, the British weekly *Nature,* was the first to provide bridges to help the broader readership grasp the technical content, and *Science* has followed suit. First, a new "This Week in *Science*" page has one-paragraph teasers for several interesting technical articles in the issue (including those on the Mars rock, comet collisions and Jupiter's winds). Also, there are now more commentaries, exemplified by the Mars rock essay by veteran science journalist Richard Kerr and a short report on the future of Mars exploration, based on the just-released National Research Council report, "Review of NASA's Planned Mars Program." *Science* also now prints perspectives by independent scientists, like Tetsuo Yamamoto's introduction to Edgeworth-Kuiper belt objects.

A review of a recent conference on the origin of life describes analyses of the Murchison meteorite, which has highlighted the role of asteroids in bringing to Earth some ingredients perhaps necessary for the origin of life. Murchison, a shower of more than 100 kilograms of carbonaceous chondrites that rained down on Australia, is still yielding precious new data 27 years later. (Reviewing another meeting on the same topic in the August 15th issue of *Nature,* planetary scientist Chris Chyba describes how asteroids and comets actually impeded the development of life—on Mars as well as on Earth. He goes on to extol recent discoveries of extrasolar planets that may bode well for the prevalence of life-sustaining environments in the universe.)

There is still more fascinating planetary research in the August 16th *Science.* Spurred by the *Galileo* probe's finding that Jupiter's winds do not decay with depth, Keke Zhang and Gerald Schubert of UCLA have modeled how convective motions deep within Jupiter penetrate upward through stable zones, to be manifest as the zonal wind pattern in the giant planet's belts and zones. The same issue also reports studies by Lawrence Livermore Laboratory researchers on the electrical conductivity of Jupiter's interior; they conclude that its magnetic field may originate much closer to its surface than had been thought.

Banged-up Comets

The classical reservoir for comets is the enormous, spherical Oort cloud of remnant planetesimals, far beyond the orbit of Pluto, created when primordial bodies were scattered by the gravity of the early gas giants (Jupiter, Saturn, Uranus and Neptune). Another reservoir, the Edgeworth-Kuiper (E-K) belt, lies just beyond Neptune's orbit. But, paradoxically, it holds what were once the outermost planetesimals in the solar system: they just never formed into a transneptunian planet. Paolo Farinella and Donald Davis simulated on a computer how E-K objects collide with one another. Although we expect E-K comets to be compositionally primitive, they must have experienced many fragmenting collisions, and thus may no longer physically resemble early planetary building blocks. Since we don't know what comets are really like, we can't be sure what happens when they bump into each other, so I'm skeptical that the simulations are fully realistic.

A final planetary paper in the August 16th *Science* is by Richard Binzel, editor of The Planetary Society's *The NEO News,* who reports discoveries about the relationship of some Earth-approaching asteroids to meteorites.

Cruising *Science*'s Web page (http://science-mag.aaas.org/science/home/browse.shtml) for the planetary tidbits in the August 16th *Science* is disappointing. Although you can print out the full Mars rock article and Kerr's commentary, everything else I've discussed is represented only by abstracts or one-line "summaries." But the Web site provides a fine index to *Science,* beginning with October 1995 issues.

Clark R. Chapman is an institute scientist at the Boulder office of the Southwest Research Institute.

A Great Year

by Louis D. Friedman

What a great year 1996 has been for NASA, and for planetary exploration. This is a good time to reflect on the change that has taken place in NASA. Five years ago, The Planetary Society was engaged in a virtual war with the space agency. We were objecting to its decision to delay *Mars Observer* and future planetary missions to provide more funds for the space station. We protested its focus on bigger budgets for fewer programs and missions. Now, a sense of accomplishment and achievement pervades the agency, with wonderful results pouring in and a set of exploratory missions preparing for a new age of discovery.

Of course, hanging over the agency are the projected budget cuts, difficulties in meeting ambitious goals, complicated intra-agency and international agreements, and a set of underfunded missions—always one step from some calamity. But consider these accomplishments:

- The discovery of possible past life on Mars
- New images of the Europa ice fields, and suggestions of liquid water on that moon
- The detection of a magnetosphere around Ganymede
- Extrasolar planets confirmed around nine stars
- Stunning Hubble Space Telescope pictures of the birth of galaxies
- The *Galileo* probe's deep plunge into and sampling of Jupiter's atmosphere
- Five new near-Earth objects discovered in a civil/military cooperative program called NEAT (for Near-Earth Asteroid Tracking)
- The first Discovery launch, to a near-Earth asteroid
- Two scheduled Mars launches: an orbiter, and a lander and microrover
- Breaking of the American endurance record in orbit by astronaut Shannon Lucid
- Breathtaking shuttle–*Mir* rendezvous in space

Not a bad year. Maybe the "can do" agency is back. Kudos to NASA and to the whole space program team, in NASA centers, in academia, at research institutes—and to its international partners, and of course to the public, for its strong support.

Exciting Science

The biggest thrill of the year came on August 7. That was the day that a team of NASA and university scientists announced their finding of possible evidence of extraterrestrial life. Life on other planets—a subject humans have wondered about throughout history—for the first time appears to have substantiation. Maybe. As with all great scientific discoveries, confirmation and follow-up are needed, and implications must be analyzed. New questions will be posed, and new explanations offered.

The discovery of possible traces of microscopic life, some 3.6 billion years old, on Mars was both surprising and expected. Surprising, in that few expected these traces to be found in a chunk of rock that just happened to drop randomly at our feet as we walked on our own planet. Expected, because of the fascinating story about Mars that had begun to unfold from spacecraft data: a warmer and wetter past, not too different from Earth's early formative years; running water on its surface, even lakes and, possibly, oceans; huge early bombardments that caused explosions so violent as to send rocks from Mars into interplanetary orbits. Moreover, we have important data from comparative studies on Earth: the quick formation of unicellular life-forms within the first billion years of the planet's formation, and the discovery of life-forms that survive in extreme environments, sometimes even without oxygen and sunlight.

This is exciting science—piecing together different clues gained from diverse exploratory efforts, leading to new paths for human thought and endeavor, and offering questions for us to pursue.

Results from Europa and Ganymede are also raising questions for further pursuit. The *Galileo* images returned this past year remind us of why scientists are always seeking higher-resolution cameras. With each increase in resolution, they learn something new, deepening and often changing their understanding of these other worlds. The biggest surprise of the *Galileo* year may have been an invisible one: the discovery of a magnetosphere at Ganymede. That result, just like the ones from inside Jupiter's atmosphere, has put the theorists back to work trying to understand the formation and evolution of the solar system.

Planets in our solar system—at least that was a known subject. In the last year we have been finding them around other stars. We now have comparative solar system-ology, in addition to the new field of comparative exobiology.

The results from the human spaceflight program are not usually counted as planetary or space science results. But, the record-breaking flight of Shannon Lucid and the continuing development of Russian–American joint missions directly prepare us for human flight to Mars. Progress is being made toward that goal in the two countries' now essentially merged space station programs, and in the studies being conducted at NASA's Johnson Space Center.

Looking Ahead

As the year ends, we are hoping for successful launches to Mars (two by NASA and one from the Russians—very important to us also). These follow the successful launch of the Near-Earth Asteroid Rendezvous in February. As those spacecraft wend their way through interplanetary space, they carry, in addition to their science payloads, the hopes of all of us that the great year of 1996 will be succeeded by an even greater one in 1997, then in 1998, and on and on.

NASA has once again become a symbol of what we want from government—innovation, efficiency, accomplishment and excellence. It isn't perfect; surely my friends and colleagues in NASA and at the Jet Propulsion Laboratory know I often spend a lot more words criticizing than I am doing here praising. But I also think it important to note that this government program of space science and planetary exploration is unmatched anywhere in the world. It is not a private enterprise or small band of hardy enthusiasts that is doing this space exploration, but a government bureaucracy.

Usually I write in this space about problems and worries—mostly in the politics of space programs. Singing praises is not my usual pastime. But, the gifts we have received from the NASA team this amazing year truly deserve a thank-you.

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

Society News

This photo of the July 1991 solar eclipse was taken from San José del Cabo, Baja California, Mexico, by Cliff Holmes

Chasing the Eclipse in '98

The Planetary Society is pleased to offer members two different tours to view the total solar eclipse on February 26, 1998—a Caribbean cruise, and a land tour to Aruba that includes an optional visit to the *Ariane* launch site in French Guiana. The eclipse will have a totality duration of three minutes and forty-three seconds, promising wonderful opportunities for both viewing and photography. Space is limited on these tours and will fill up quickly. Please contact me at Society headquarters for a free brochure (e-mail, tps.sl@mars.planetary.org).
—Susan Lendroth, Manager of Events and Communications

Red Rover Grant

The Kenneth T. and Eileen L. Norris Foundation of Long Beach, California, has provided partial funding for our Red Rover, Red Rover project—specifically for educational materials to be used by the students. The foundation has been a longtime supporter, having helped in the past on education projects such as MarsLink. Our sincerest thanks.
—Louis D. Friedman,
Executive Director

Wanted: Mars Explorers

The Planetary Society is accepting nominations for the Thomas O. Paine Award. The Society presents this award to the group or individual who has done the most to advance human exploration of the Red Planet.

In July, at Planetfest '97, the winner of the award will receive a memorial plaque and a Mars flag designed by Paine himself. A cash award of up to $5,000 may also be presented if the award selection committee feels such a honorarium can materially assist work advancing Mars exploration.

The deadline for nominations is February 1, 1997. For more information and for the official nomination form, contact Society headquarters.
—Michael Haggerty,
Information Services Manager

New Addresses in Cyberspace

We have revamped our e-mail system. Here are some new addresses you might find helpful: tps@mars.planetary.org, for general Society information; tps.members@mars.planetary.org, for membership questions and renewals; tps.sales@mars.planetary.org, for sales requests and orders or catalogs; tps.des@mars.planetary.org, for Members' Dialogue letters and contributions to Questions and Answers.
—MH

United Nations Workshop

Planetary Society Executive Director Louis Friedman and planetary scientist Adriana Ocampo addressed attendees at the United Nations 1996 Workshop on Basic Space Science in Developing Countries. The workshop, a cooperative effort of The Planetary Society, the UN and the European Space Agency, was held in Bonn, Germany, in September. It included representatives from more than 20 nations. This was the sixth such workshop the Society has cosponsored. Two years ago, at a workshop held in Egypt, Ocampo and planetary scientist Chris McKay initiated a project to develop a Mars drill for the Russian Mars Rover. We will report on the progress of that project in a future issue of *The Planetary Report.* —*SL*

Newsletter for Future Martians

MarsLink has evolved, through the efforts of the Arizona Mars K-12 Education Program, into a new kids' science newsletter, *Red Planet Connection: The Science Resource for Future Martians,* which links students to real-life efforts to explore Mars. There are separate versions for K-2, 3-5, and 6-8 grades, plus a teachers' edition.

The quarterly publication includes science and interdisciplinary activities, puzzles, news about Mars exploration and career path information. One-year subscriptions are $30 per package of 30 copies plus a teachers' edition.

For more information, or for free samples, contact T. Dieck at the Arizona Mars K-12 Education Program, Department of Geology, Arizona State University, Box 871404, Tempe, AZ 85287-1404; e-mail, saelens@imap2.asu.edu.
—Ken Edgett, Editor,
The Mars Underground News

More News

The Mars Underground News:
Discovery of possible martian life-forms…the Case for Mars conference…images of Mars.
The Bioastronomy News:
The 1996 symposium on bioastronomy…possible oceans on Europa.
The NEO News:
Special report on the Near-Earth Asteroid Rendezvous…comet Hyakutake…discoveries in meteorites.

For more information on these newsletters, please contact Planetary Society headquarters: see page 2.

Questions and Answers

How much of a meteor shower is a localized phenomenon? That is, do people in far-ranging locales witness the same meteors in a particular shower? Or are the particles that cause the shower so abundant that observers in different places see different meteors? If so, what is the approximate viewing range for a particular meteor?

—Rhett Lawrence,
Waycross, Georgia

Earth can spend hours to days crossing a meteoroid stream, a collection of particles following nearly parallel orbits around the Sun. The passage generates observable meteors ("falling stars") in our atmosphere as the individual meteoroid particles collide with the atmosphere and burn up. Traveling around the Sun at 29 kilometers (18 miles) per second, Earth passes through a large volume of space during even a short-duration meteor shower. Multiply the duration of the shower (in seconds) by Earth's speed to determine the length of the meteor zone. For example, the potentially strong Leonid meteor shower in November 1998 may last only about three hours, or 10,800 seconds (3 times 60 times 60). Earth will travel 10,800 times 29 = 313,200 kilometers (194,400 miles) during this period. With its diameter of 12,756 kilometers (7,928 miles), Earth's disk covers an area of pi times the radius squared—128,800,000 square kilometers (49,363,000 square miles) and will sweep through a volume (area times travel distance) of 40 trillion cubic kilometers (9.6 trillion cubic miles)—a lot of space!

Meteors can be observed, in some fashion, all over the hemisphere facing the inbound stream. "Observed," in this sense, means with radar methods where there is daylight on the facing hemisphere, as well as visually, photographically or electronically on the nightside of the facing hemisphere.

Observed meteor speeds in the range of 11 to 70 kilometers (7 to 44 miles) per second give a hint of the spacing of the parent meteoroid particles. High-rate annual showers generate perhaps 60 meteors per hour, or one per 60 seconds. That means the meteors must be separated by anywhere from 660 to 4,200 kilometers (about 420 to 3,100 miles). Even two meteors appearing within a second of each other are separated by several kilometers in space.

Observers on the facing hemisphere will not all see the same meteor. Living on a spherical planet sets one kind of limit. For the average meteor burning up 100 kilometers (62 miles) above the surface, observers within a circle (centered below the meteor so that it is directly overhead) about 1,135 kilometers (705 miles) in radius could see it on the horizon. If they are closer to the center of the circle, they can see it higher in the sky. Outside that circle, the meteor is below the horizon. As a rule, seeing a meteor on the horizon is difficult at best, so in practice observers must be closer than about 670 kilometers (400 miles) to see the same meteor.

How far a meteor can be seen is a function of how bright it is, and there are many more faint meteors, not detectable by the eye even directly overhead and 100 kilometers up, than there are bright ones that can be seen. So for a meteor to be seen by two distant observers, it must also be bright.

—STEPHEN J. EDBERG,
Jet Propulsion Laboratory

The author captured this glimpse of a Perseid meteor in August 1980 from California's San Gabriel Mountains.

Factinos

Scientists at JPL have discovered a unique and baffling object that may be a strange asteroid or an extinct comet. The object, designated 1996 PW, was discovered this past August by scientists using data from the Near-Earth Asteroid Tracking (NEAT) program, which uses a JPL-developed camera mounted on a United States Air Force telescope atop Mount Haleakala in Hawaii.

"This is a misfit in the grand scheme of things," said Eleanor Helin, a planetary astronomer at JPL, and the NEAT principal investigator. "At first look, the object appears to be an asteroid, a chunk of rock that orbits the Sun," she said. But, unlike most asteroids that inhabit orbits no farther out than Jupiter, 1996 PW has a highly elongated, comet-like orbit that stretches into the outer reaches of the solar system far beyond Neptune and Pluto. According to JPL's Michael Keesey, its orbital period is estimated at 5,000 years.

"Although 1996 PW's orbit resembles that of a long-period comet," Helin added, "no gaseous emissions or other normally expected, comet-like activity has been observed, even during its current closest approach to the Sun."

—from NASA

◆

Venus' lofty highlands may be coated by a frost of the rare, silvery-white, nonmetallic element tellurium. Gordon Pettengill of the Massachusetts Institute of Technology suggests that this is why the planet's highlands appear so bright in radar images. Recent analysis of *Magellan* radar data eliminated metals such as iron pyrite because the mystery material is very glossy, making it more of a semiconductor, unlike most metallic minerals which are high conductors. Tellurium has the right amount of conductivity and freezes out of the atmosphere at exactly the temperature corresponding to that of the altitude on Venus where the edges of this bright material are seen.

—from *Astronomy*

Basics of Spaceflight:

Flying a Robotic Interplanetary Spaceship

by Dave Doody

"Temperature, this is Systems, what's your status?" The intercom button lights up and pulsates to the sound of voices spoken into handsets.

"This is Temp. Go for the enable."

"Propulsion, this is Systems."

"Propulsion is go."

"Power, Systems."

"Power, go!"

"Telecommunications?"

"Telecom, go!"

"Science, Systems."

Marv looks up to review some of the columns of numbers on his overhead digital display, numbers that have just completed a journey across interplanetary space from *Voyager 2*'s science instruments. Tim, the systems engineer, repeats: "General Science, this is Systems!" Eyes still on his data display, Marv reaches over and picks up his handset. Squeezing the talk button, he answers, "General Science."

Tim responds, "General Science, this is Systems. What's your status for the mag-roll maneuver enable?"

Voyager 2's magnetometers are among the science instruments Marv is responsible for monitoring today, the "mag" in the mag-roll maneuver. *Voyager 2,* which normally maintains a fixed attitude, will rotate for a little while, sweeping its longest appendage around in circles while keeping its large, dish-shaped antenna staring at the tiny, distant Earth. The magnetometers are mounted on a fiberglass boom 13 meters (43 feet) in length, far away from any magnetism generated by the spacecraft. Sweeping them around in a circle will permit these instruments to capture data about the magnetic fields deep in interplanetary space, beyond Saturn. All the detailed instructions for this maneuver had been sent up to *Voyager 2* a few days before, and only one more command, the "enable," is necessary to let the maneuver begin on schedule.

Marv speaks into his handset: "Go."

Tim continues the litany: "Attitude Control, Systems."

"Attitude, go for enable."

"Data Systems?"

"Go!"

A Go for the Enable

In a glass-walled "cage," the mission controller looks across the room and catches Tim's eye. Then Tim calls on the intercom: "Ace, Systems, we are green for the enable." "Ace" is the mission controller's call sign on the intercom. The name implies a single point of contact for operations.

"Roger," responds the Ace ("roger" is short for "I understand your message"). He punches the intercom button labeled "FLT OPS MGR," causing it to light up, and calls, "Flight Ops Manager, Ace." Through the glass wall, the Ace watches the manager, Doug, lean forward to pick up the handset near his desk. With a pleasant hint of a Virginia accent, he answers, "Ace, this is the Flight Ops Manager."

"Doug, we have a green from Systems to enable the mag-roll."

"Is everything on the ground OK?" Doug asks. He's referring to the condition of the Deep Space Network of tracking stations around the world; there were some minor problems that morning with an antenna system at Madrid. The Ace makes one more scan of some displays. "Affirmative."

"You have a go for the enable, Ace."

The Ace responds, "Roger that!" and turns to the command system terminal glowing green behind him. Typing in "MODE, IDLE-1" causes the display from Australia to respond "IDLE1/IDLE1" after a few seconds. Turning back around to the intercom mounted on the console, he punches another intercom button, which lights up. "Data Systems Engineer, Ace."

Tracy responds on the intercom, "Ace, this is DSE."

"I have attached to the queue at Australia, file number 321989, the mag-roll enable command, set to radiate over Deep Space Station 42 at 18:25. It's standing by for your verification."

Tracy replies, "File 321989 is approved."

"Roger." The Ace turns back around to the command terminal and types another directive in green letters: "MODE, ACTIVE." The display responds in a few seconds "ACTIVE/IDLE2." The command subsystem in Australia automatically counts down to 18:25, and then the display goes "ACTIVE/ACTIVE," showing that the command has started its long trip, bit by bit, to *Voyager 2*. At the speed of light, it will travel for hours to get there.

The Mission Controller's Job

This particular activity took place 11 years ago, when *Voyager* was still free-falling along its trajectory from Saturn to Uranus; the mission controller was yours truly. Many things have changed since then, mostly becoming more automated and somewhat less formal. Although the systems, the computer interfaces, and the spoken words and procedures are different, interplanetary flight operations are still typically conducted using computer displays and voice communications over intercom systems. *Voyager 1* and *Voyager 2*, today more distant than any planet, still execute mag-roll maneuvers periodically and make many other scientific measurements of their remote environment to report home.

Two **Cassini** *operations engineers, Joseph Hunt and Lee Mellinger, acting as "Aces" during a recent test, communicate with the partly assembled spacecraft in another building.*

Photo: JPL/NASA

Most interplanetary robotic flight projects have an Ace who coordinates real-time operations among the people of different teams, both within the project and external to it. The Ace also makes sure that all the various types of data always flow properly in real time to the right places; that commands are installed on the spacecraft bit for bit; that valid tracking data are captured for the navigators; that telemetry data flow to the spacecraft engineers and the scientists and are stored properly in on-line databases and archives for future reference; that monitor data and quality-control data continuously show conditions in the ground data systems; that all the necessary ancillary files are in place. These operations are called "real time" to differentiate them from such non-real-time activities as the painstaking advance planning, or all the data analysis that takes place later on.

Who Does What

Let's use the analogy of a passenger ship cruising the oceans toward some mysterious exotic destination to illustrate some of the aspects of interplanetary flight operations. The captain of the ship would be analogous to the spaceflight project's flight ops manager (called the mission director on some projects). The captain knows what should be going on in the ship, where the ship is, how to reach the destination, what if anything might be needing attention on the ship, and any special events that may be coming up. But you probably won't see the captain actually handling the helm. That person at the helm is just one of the crew members carrying out the captain's orders. He or she doesn't run the ship, only steers it.

The Ace would be the helmsperson. He or she doesn't decide where the spacecraft is going, how fast it is supposed to go, or what exactly it is going to do next Wednesday. These decisions are all made in due course within the project, thanks to the work of mission designers, planners, spacecraft systems and subsystems engineers, navigators, schedulers and many others. Commands that the Ace sends to the spacecraft have usually been planned far in advance and have been put together into carefully designed and tested sequences.

The cruise ship's crew, like a robotic spaceflight project's crew, is made up of many different specialists, such as navigators, engineers and technicians, as well as the staff whose job it is to serve the passengers. On the cruise ship, the helmsperson might communicate with the people in the engine room, or receive information or instructions from the navigator. All are constantly ready to lend a hand to ensure the safety and success of their voyage. This is basically how a spaceflight crew works together as well.

High-level project managers in the spaceflight operation would be analogous to the managers of the cruise line company—the ones responsible for commissioning the cruise ship, hiring the captain and crew, and managing such activities as making sure all the resources are available to sail, and overseeing marketing efforts to attract passengers. The manager of a spaceflight project handles contracts with NASA, and perhaps other entities such as the European Space Agency. He or she manages the efforts to design, fabricate and ultimately operate the spacecraft in flight.

But passengers are the primary reason for having a cruise ship. Who are the passengers on a robotic interplanetary spaceship? In our analogy (although there is nobody physically aboard the robot spacecraft), we could say the passengers are the scientific investigators intent on collecting data about a distant planet: science observations are the primary reason for having an interplanetary flight project. Imagine that all the passengers on our hypothetical cruise ship are reporters for major magazines or news media, and they come aboard carrying all their camera equipment, notepads and tape recorders, ready to document the adventure to an unknown land. Likewise, our spacecraft "passenger" scientists have typically designed and installed all the cameras and other scientific instruments on the spacecraft, and they will be responsible for remotely operating them in flight to gather and return data.

Our oceangoing reporter-passengers might send correspondence to their home offices by using the ship's telecommunications facilities, analogous to the spacecraft sending telemetry to Earth, eventually to the scientists' institutions. The reporters' customers are the general public, who will eventually read the stories they produce describing their exotic destination in all its detail. On a spaceflight, the scientific investigators will report their findings in the scientific literature to the scientific community, and to their ultimate customers, the worldwide general public.

Details about many of the topics mentioned here, such as the Deep Space Network, telemetry and tracking data, may be found in previous issues of *The Planetary Report*. In the next installment, we'll look at the flow of data from beginning to end: Just how does the view of a planet or other object in front of a distant spacecraft's camera make it all the way to your TV set, or to your computer on the Internet?

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/.

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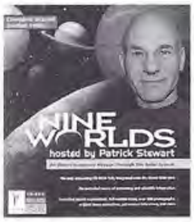

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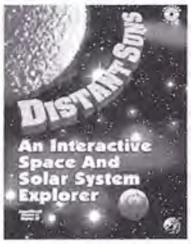

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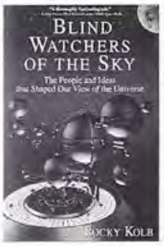

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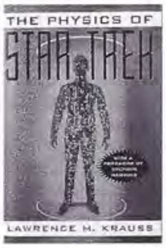

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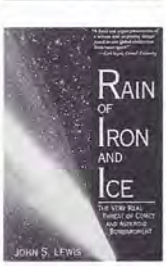

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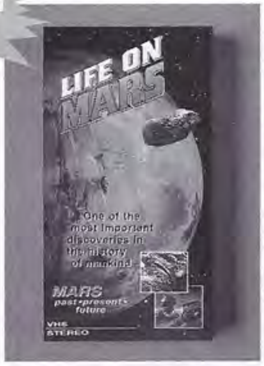

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Daniel D. Durda is a research associate at the University of Arizona's Lunar and Planetary Laboratory. His research interests include the formation and detection of asteroids, and the collisional and dynamical evolution of main-belt and near-Earth asteroids and interplanetary dust.

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