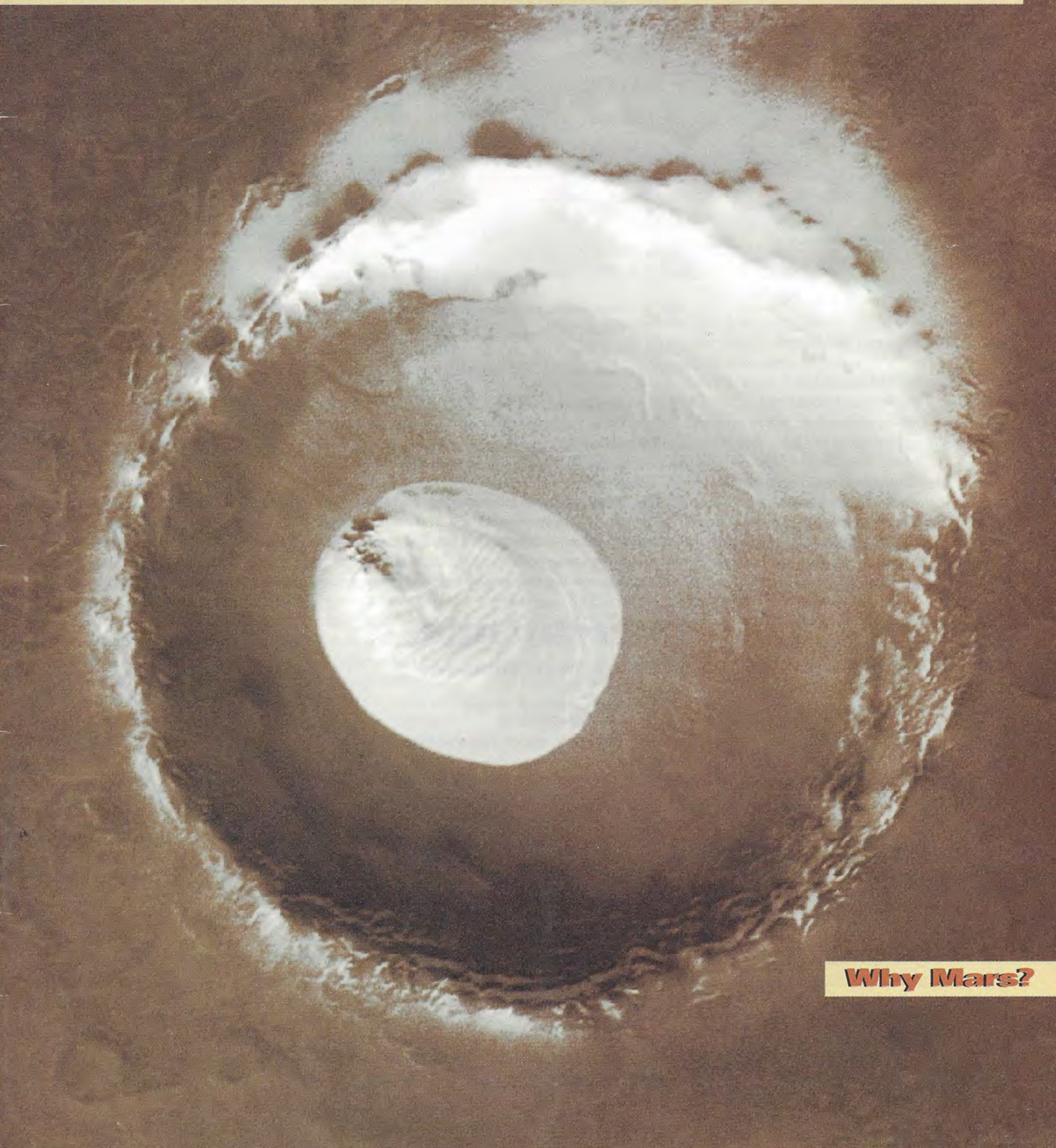
The PLANETARY REPORT

Volume XVI Number 5 September/October 1996



Why Mars?

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On the Cover:

The behavior of frosts on Mars may sound like an arcane subject for study, but when you consider that those frosts are made of carbon dioxide and water, and that water is a key to life, the importance becomes clear. This is a crater near Mars' north polar cap, which, like Earth's, maintains a permanent covering of frozen water. This crater also retains a permanent layer of frost, unlike other craters of similar size, shape and location. Why some craters defrost while others don't is one of the many enigmas of Mars.

Image: Mike Malin

From The Editor

It's August 10, the Saturday after the NASA announcement. Finally, the phones have stopped ringing, news has stopped pouring in, I've finished the article you'll read on page 14, and there's a moment to catch my breath.

This has been the biggest news to break since The Planetary Society began: NASA scientists have found possible evidence of fossil life on Mars.

The tremendous public response to the revealing of evidence only hinting at life on Mars vindicates the Society's long and often lonely struggle to convince politicians and policy-makers that people really do care about other planets.

And our stand has been recognized. Reporters calling us for quotes frequently commented that the Society had been there before everyone, extolling Mars as a world of extraordinary possibilities and insisting that the public cared deeply about those possibilities.

We continue that work, buoyed by this discovery. The news came as we were finishing this issue, giving us time only to replace World Watch with a short report on the evidence and slip in a new News and Reviews. Our January/February 1997 issue will report in depth on the findings. Stay close.

—Charlene M. Anderson

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Members' Dialogue

The Debate Continues

In the May/June 1996 issue of *The Planetary Report*, Ernst Mayr states that an independent origin of life would probably result in life-forms drastically different from those on Earth. These life-forms might be able to live within parameters and environments also drastically different from those on Earth, which may well increase the scope for life in the galaxy. Our type of carbon-based life fit the parameters on one planet, and an alien race may find it remarkable that we live at the bottom of such a corrosive, reactive and poisonous (oxygen-rich) atmosphere. We may be too cautious in our search.

It could be that a rapidly changing environment over geological time spans is required to encourage the emergence of intelligence as a survival *necessity* rather than a chance roll of the evolutionary dice, since it is clearly demonstrated on Earth that intelligence is not necessary for long-term survival of a species. Intelligence may have been a long time coming on Earth because the planet was not stimulating *enough* over long periods. The long reigns of the archaebacteria, amphibians and dinosaurs may illustrate periods of general, undemanding quiescence and ultimate stagnation in the environment.

Perhaps we should be looking for those solar systems with a less than seemingly ideal range of planets and environmental zones, ones that are subject to demanding changes.
—R.J. STEWART,
Rhayader, Wales

With Mayr and Sagan, it appears that humans are the products of impersonal and purposeless forces. That there could also be a supernatural process at work in the appearance of intelligent life on Earth is not a consideration.

Mayr is pessimistic and Sagan is optimistic about what evolution can accomplish. If evolution is not the whole story whereby intelligent life can appear on a hospitable planet, this debate can be misleading. Further, this can harm the prospect of obtaining wider support for the SETI project.

As far as communicating over great distances—humans on Earth have already transmitted extremely powerful radio signals into the universe. For each of more than 300 United States and Soviet atmospheric nuclear weapons tests, there was a powerful electromagnetic pulse (EMP) in the radio spectrum. For tests from 1946 to 1962, these pulses are now 33 to 50 light-years away. Any alien society that has developed nuclear technology and detects these pulses will know their source and that the pulses did not occur naturally. Aliens may be looking for more EMPs and trying to decode them. This raises the prospect of using, and possibly focusing, EMPs for space communication. Likewise, we could possibly detect EMPs from any society conducting nuclear tests in its atmosphere or using EMPs for communications.

My hope is to get ham radio enthusiasts to monitor for EMPs. My prayer is for an early and dramatic success for SETI.
—TOM McCRAW,
Cascade, Maryland

I discovered, while rereading your marvelous article about intelligent life in the universe, a serious kind of anthropocentrism disguised as scientific objectivity. The belief that life on Earth was an "accident" requiring gobs of time is the final chauvinism. It is as if to say, "We can no longer think of ourselves as the center of the universe or the pinnacle of creation, but, by gosh, ain't nobody out there gonna look or smell like us!"

The discovery of amino acids in the interstellar medium is the final blow to the belief in the uniqueness of Earth's life-forms. The RNA structures that were the first builders of cells and DNA are profoundly complex, yes, but they are nevertheless "fuzzy crystals" that form by the natural laws of physics just as "hard crystals" such as diamonds or ice do. Carbon or water crystallized anywhere off-world would still be diamonds and ice. Why do we need to believe that RNA must, by necessity, crystallize in other ways off-world?

If events on Earth obey the same physical laws that rule the rest of the universe, and if life formed out of the physical action of amino acids in Earth's new world environment, then the formation of life through physical action is one of the laws of the universe. Therefore, formation of "fuzzy crystals" of RNA, as precursors of DNA, will take place under any suitable circumstances anywhere in the universe, and the laws by which DNA functions will be the same.

By declaring life on Earth to be an accident, we are still demanding the uniqueness of special creation; we are just cloaking it in suitable scientific terminology. The assumption that life elsewhere must be different is the last gasp of the medieval view of the universe, rejecting special creation by rewording it.
—RAMONA LOUISE WHEELER,
Rockland, Massachusetts

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PLUTO:

New Views From the

We don't know much about Pluto. It is the last-discovered planet in our solar system, swimming into our ken only in 1930 when the young Clyde Tombaugh of Lowell Observatory noticed a faint dot that had moved across a series of photographic plates he had taken in the search for the hypothetical Planet X. The planet has since revealed very little of itself, and new information has come in very small increments.

After years of painstakingly tracking its path, astronomers learned that Pluto follows an orbit that is more highly inclined (tilted relative to the plane of Earth's orbit about the Sun) and more eccentric (elliptical rather than circular) than the orbit of any other planet in our solar system. It is usually the farthest planet from the Sun, but every 248 years it crosses Neptune's orbit. Pluto is now the eighth planet out and will remain so until the spring of 1999.

In 1978, James Christy of the United States Naval Observatory noticed what appeared to be a blob stuck onto the faint disk of Pluto and, along with Robert Harrington, quickly realized that this must be a satellite orbiting the planet. Christy named the new world Charon, after the ferryman who carried dead souls across the River Styx to the underworld ruled by Pluto. (It is a discoverer's prerogative to name newly found planetary bodies, and Christy pronounces Charon as "shar-on" rather than "kair-on" as it would be pronounced in Greek. By no coincidence, Christy's wife is named Charlene, which is pronounced with a soft "sh" sound.)

With the discovery of Charon, and with observational and theoretical studies of the two bodies, astronomers were able to get a good idea of Pluto's size: It's about 2,300 kilometers (1,430 miles) in diameter, or about two-

This was the best image of Pluto and its moon Charon taken before the images that follow on pages 6 to 9. The Faint Object Camera of the Hubble Space Telescope collected the data early in 1994. The disks of both the planet and its moon appear featureless here, but, as you'll see in the newer sequence, surface features began to appear.
Image: NASA/ESA

Hubble Space Telescope

American astronomer Percival Lowell had predicted, based on perturbations of Uranus' orbit, that another planet circled our Sun out beyond Neptune. Lowell devoted part of the considerable resources of his observatory in Flagstaff, Arizona, to the search for this Planet X. Lowell died in 1916, but the work continued and in 1930 a young astronomer named Clyde Tombaugh found the suspected planet. It betrayed itself as a tiny dot that moved from night to night against the background of fixed stars.
Photographs: Lowell Observatory

thirds as large as Earth's Moon. Charon is about 1,200 kilometers (740 miles) in diameter, making it the largest moon in our solar system relative to its parent body—half the planet's size!

And what are these worlds some 6 billion kilometers (3.7 billion miles) from the Sun made of? Rocky materials probably dominate their interiors, and water ice is another likely major constituent. Scientists have detected frozen methane, carbon monoxide and nitrogen on Pluto's surface, while Charon displays the spectrum of water ice. The presence of these compounds may help explain Pluto's appearance.

Pluto seems to have the most contrasty surface of any planet in the solar system—except Earth, with its homey mix of bright water ice and clouds, dark liquid oceans and changing inhabited land. In the deep freeze of the outer solar system, the temperature of Pluto may rise to only 40 to 60 degrees Kelvin, so volatile compounds such as methane, a gas on the balmy Earth, would freeze solid. Reacting with ultraviolet radiation from the Sun, such substances can form a tarry covering over the brightest water ice, and this may explain the dark mottling of Pluto's surface.

Until we send a spacecraft to explore Pluto, we can increase our knowledge only minimally. In 1999, an advanced camera is scheduled to be installed on the Hubble Space Telescope, and that may provide a slightly better view of Pluto. Even with it, this distant world will remain a blurry amalgam of blotches. To really get to know Pluto, we'll have to send a robot equipped with electronic probes that can send back to Earth a clear view of the planet.

The advanced Pluto Express mission now being planned could launch shortly after the turn of the century. This may be the best chance of our lifetimes to explore this mysterious world. Pluto passed its perihelion, or closest point to the Sun, in 1989, and it is on its way out. The mission is now under development at the Jet Propulsion Laboratory, but in this time of shrinking budgets, its future is uncertain. With this small spacecraft, humans could complete the reconnaissance of the solar system and bring Pluto into focus. We have the ability to explore Pluto. It remains to be seen if we have the will. —***Charlene M. Anderson***

While carefully studying photographs of Pluto during a project to refine the planet's orbit, Jim Christy of the US Naval Observatory noticed a blob stuck to the side of the planet. He and Bob Harrington discussed alternatives that could explain this, and further study of photographs revealed that the blob traveled around the planet every 6.4 days. The best explanation was that Pluto had a moon, since named Charon by its discoverer.
Photograph: US Naval Observatory

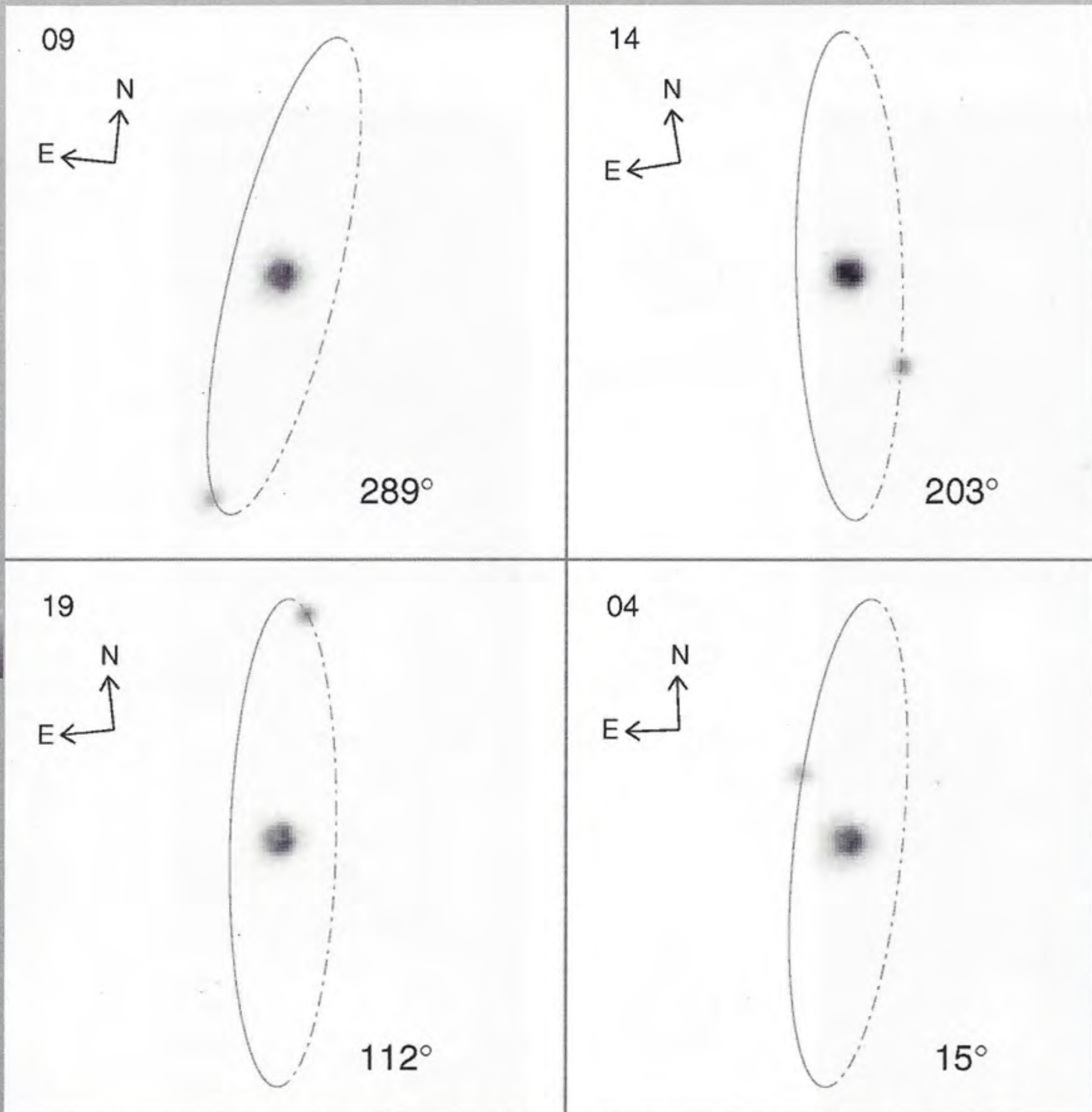
About These Images:

These images were created from a series of exposures taken by the Faint Object Camera on the Hubble Space Telescope over four days in late June and early July of 1994. Alan Stern of the Southwest Research Institute, Marc Buie of Lowell Observatory and Laurence Trafton of the University of Texas at Austin then spent months analyzing what the telescope saw. The data were extensively studied and computer-processed to bring out as much detail as possible. In March 1996, these researchers released their results at a major Washington, DC, press conference. The images you see here are not those released at the conference, however, but more finely tuned versions resulting from the researchers' continuing analysis of the data. Their work, including these images, has been submitted for publication in the *Astronomical Journal* later this year.

Charon Orbiting Pluto

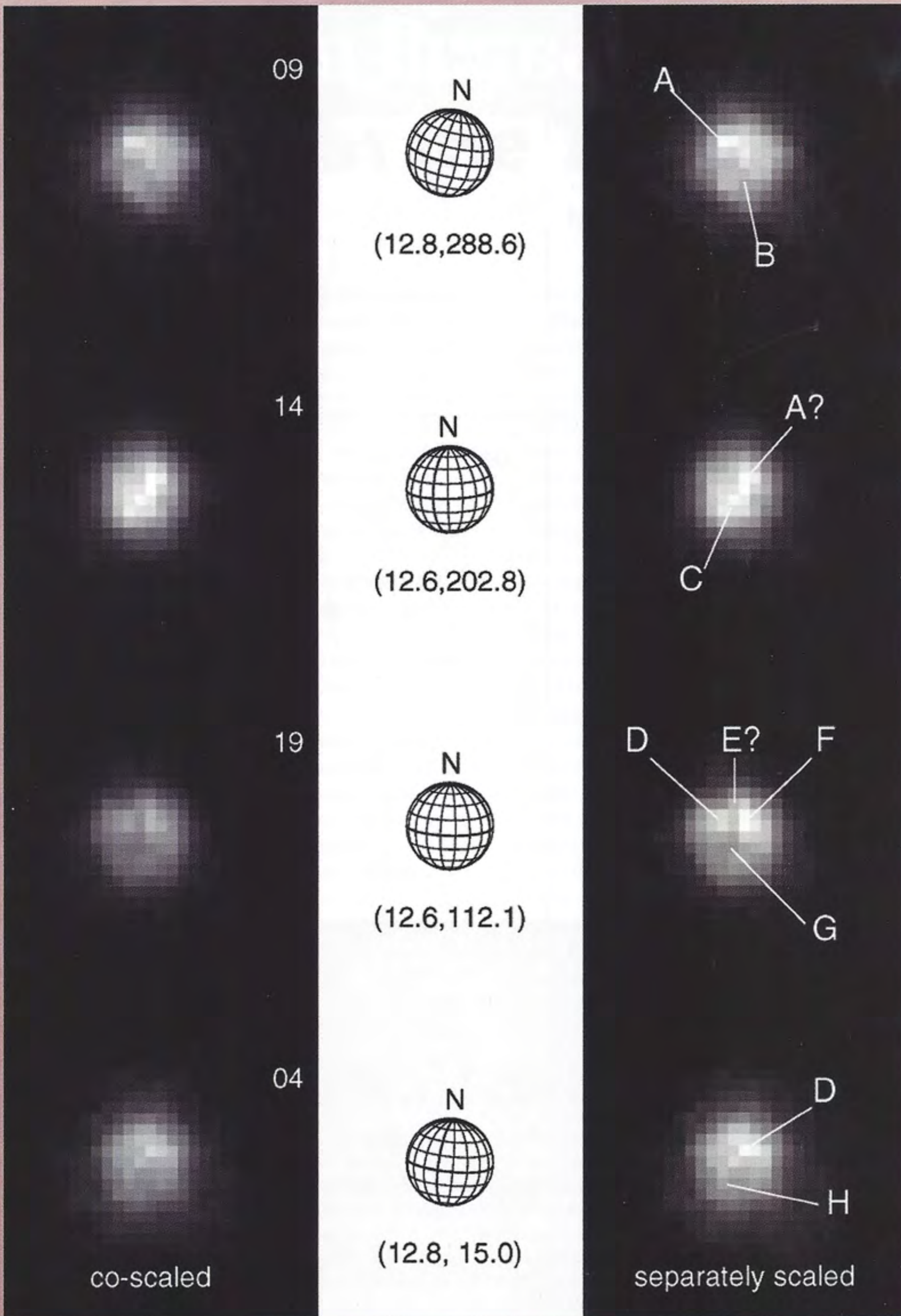
Pluto's large moon, Charon, orbits the planet so closely, at an estimated 19,400 kilometers (12,050 miles), that it's hard to separate the two when looking through Earth-based telescopes. But from above Earth's interfering atmosphere, the Hubble Space Telescope has been able to distinguish the two objects clearly. In this sequence of images, we follow Charon as it loops around Pluto. The solid line indicates the half of the orbit coming toward the viewer; the broken line, the half of the orbit on the other side of the planet. The orbit appears elongated up and down because Pluto appears to rotate lying on its side as seen from Earth (Pluto's north is to the right). This tilt is reminiscent of that of Uranus, which scientists speculate was knocked on its side by a tremendous impact. Moons revolve nearly in their planet's equatorial plane, as we see Charon doing here.

Image numbers appear in the upper left corner of each image; using the numbers, you can compare these images with those on the following page. The arrows show north and east on the plane of the sky as seen from Earth. At bottom right is the longitude of the point closest to Earth at the midpoint of each HST exposure.



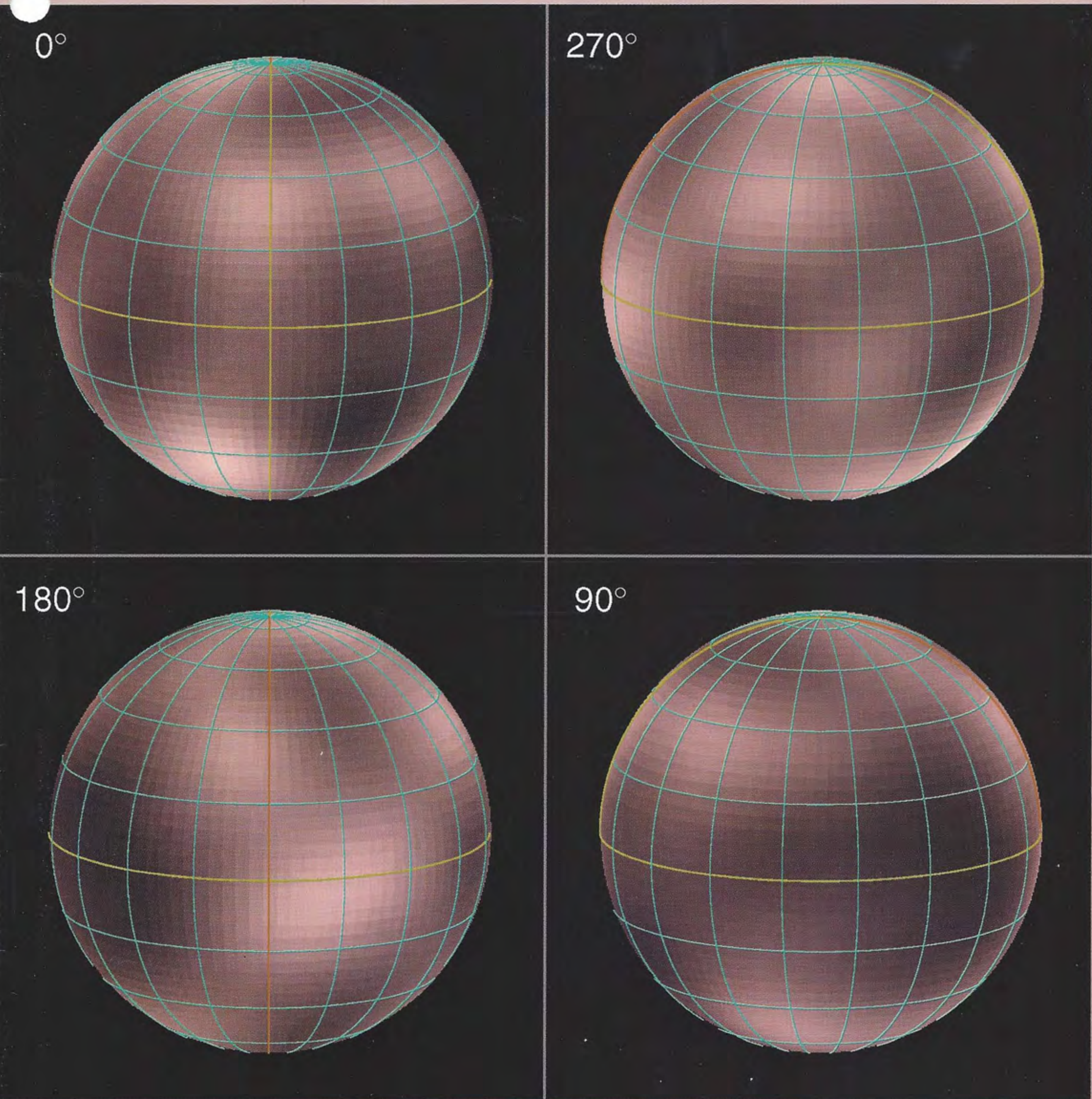
Mapping Pluto

Take the four images of Pluto from the following page and project them onto a rectangular map, and the light and dark regions might seem to resemble the continents and seas on Earth, or the bright and dark regions of Mars. But it's dangerous to make comparisons among such different bodies. It's possible that Pluto's contrasty markings are related to actual surface features, such as highlands, basins and impact craters. But it's more likely that the bright markings are painted by frosts that travel across the planet's surface as it goes through seasonal changes. Like many of the icy bodies in the outer solar system, including its close relative, Neptune's large moon Triton, Pluto is so far from the Sun and so cold that substances that are normally gases on Earth, such as nitrogen, carbon monoxide and methane, will freeze onto its surface. The bright areas are likely to be fresh frosts. The dark areas are probably older ices that have been exposed to ultraviolet sunlight and cosmic rays, which process the simple gases into more complex—and darker—organic residues. Even though they appear nearly black in this contrast-enhanced map, if seen close up the dark areas would be about as bright as dirty snow.



Rotating Pluto

This series of images shows a nearly complete rotation as the planet Pluto turns through its day, which is nearly 6.4 Earth days long. With the unprecedented detail of these images, you can follow surface features as Pluto rotates. In the right column, the most prominent features are marked by letters. Some features, such as A and D, are seen in more than one image set. The four images in this column were processed to show the most detail possible. In the left column, the images were scaled to preserve the relative brightness of the different hemispheres as the planet rotates. The center column shows the apparent size and orientation of Pluto in each image. The latitudes and longitudes indicate the point closest to Earth during each exposure.



Four Faces of Pluto

With Earth-based telescopes, scientists have seen that Pluto has a slightly reddish cast, which is not surprising if organic compounds have settled out on its surface. Combining this information with their best-resolution images, Stern, Buie and Trafton constructed these color portraits of Pluto. The views are roughly 90 degrees apart. The global color is realistic but the markings themselves may have more or less color than shown.

Why Mars?

by Carl Sagan

Mars has been a human destination for so long—in both scientific exploration and science fiction—that we might assume that everyone shares the same reasons for wanting to reach the Red Planet. In advancing the cause of Mars exploration, it can be valuable to step back and reassess the reasons for exploring Mars. That is what NASA Administrator Daniel Goldin asked Planetary Society President Carl Sagan to do. Here are his conclusions. —Charlene M. Anderson

- Mars is the nearest planet that astronauts can explore.
- About 4 billion years ago, Mars seems to have had an Earth-like climate, with rivers, lakes and perhaps even oceans. (This was at a time when the Sun was 25 percent dimmer than it is today.) Something unknown converted an Earth-like world to a deep ice-age planet. Perhaps we, who are perturbing our planetary environment, should understand what happened to the climate of Mars.
- Mars has a planet-wide ozone hole. Ultraviolet light from the Sun strikes its surface unimpeded. This is thought to be the reason that not even organic molecules were found by the *Viking 1* and *2* landers. The study of Mars, therefore, helps us understand what the extreme consequences of ozone layer depletion on Earth might be.
- In exactly the same epoch that Mars was warm and wet, life arose on Earth. Is it plausible that on two nearby planets with very similar environments, life arose on one and not the other? The search for morphological or chemical fossils of past life on Mars is one of the most exciting goals of planetary exploration. If found, it might indicate that life arises quickly on all planets in the universe where the conditions are right.
- As the martian climate degraded, life if any would have retreated to the last habitable regions, surface or subsurface. If there are martian "oases" today, could life on Mars—despite the negative results from *Viking*—be waiting to be found? If found, it might show what kinds of life—fundamentally different from life on Earth—are possible.
- Mars is an ideal arena for international cooperation in space exploration. Despite fiscal and infrastructure problems, the Russian space agency appears on track for the *Mars '96* launch and recently approved a *Mars 2001* mission plan. Mars Together remains a high-level government initiative. A Japanese Mars orbiter is scheduled to be launched in 1998. European national agencies (notably the French and German) have significant roles in current Mars missions and plan for future ones as well. The United States has an opportunity to play a key role in a new kind of coordinated scientific exploration of another planet through international combined operations.
- Mars exploration is a potential testing ground for a range of new technologies—including aerobraking and the use of martian resources to generate oxidizer and fuel for the return journey (and water and oxygen for eventual human missions). It is also an ideal testing ground for remote rover and returned-sample missions, as well as long time-delay telepresence and virtual reality.
- Because of the historic romance of the general public with Mars (consider even today the associations of the word "martian"), the exploration of Mars has a public resonance and support that probably no other goal of the space program can claim.

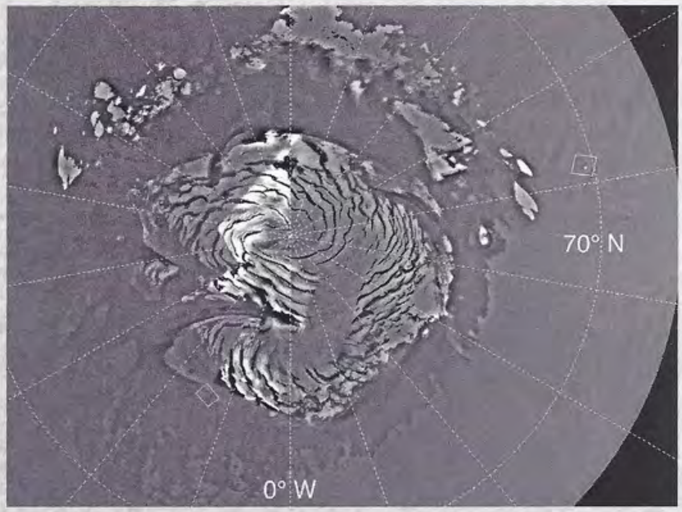
- Although the SNC meteorites (named for the places on Earth where they were found—Shergotty, Nakhla and Chassigny) provide samples of a few (unknown) locales on Mars, they cannot provide a fair sample of this heterogenous planet.
- The goal of eventual human missions to Mars provides a coherent justification for the international space station—especially if used for studies of long-duration stays (one to two years) of humans in space.
- In the long run, Mars is the prime site for self-sustaining communities on other worlds.
- On a longer term, Mars is the most readily terraformed world in the solar system.
- Mars helps to provide a hopeful dream of a positive future for our children and grandchildren. It can vividly illuminate American discipline, imagination and persistence, and an opportunity to help steer our planet out of the lingering shadows of the Cold War.

Carl Sagan is the David Duncan Professor of Astronomy and Space Studies and Director of the Laboratory for Planetary Studies at Cornell University.

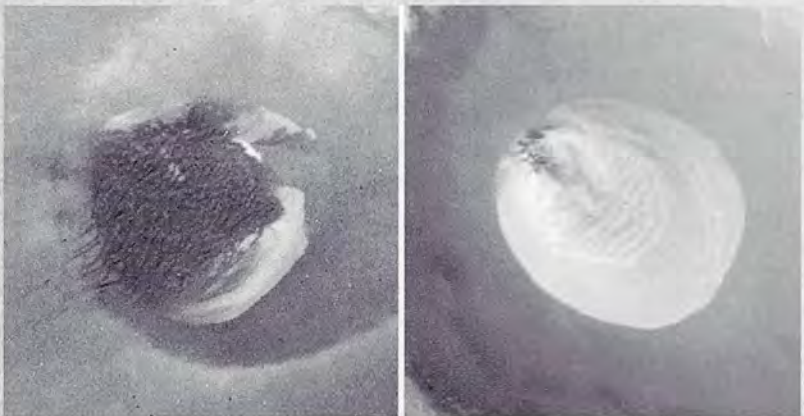
A Martian Enigma

To understand Mars, its atmosphere and surface features, we need to have a better idea about the behavior of volatile substances, such as water and carbon dioxide. As the dominant constituent of the atmosphere (95 percent), carbon dioxide plays a major role on Mars. But water is also a major player: We see evidence of its past abundance in the huge channels carved into the martian surface by ancient floods. Even today, on this frozen desert world, water plays a role. For example, the permanent north polar cap is made primarily of water ice. Both carbon dioxide and water frequently freeze out of the thin atmosphere to form frosts. When and where these frosts appear, and their relationship to the sand dunes found in Mars' polar regions, are among the most enigmatic phenomena we've yet seen on the Red Planet.

This digital image mosaic of the northern polar region, compiled from **Viking** ***orbiter data, shows the perennial ice cap (center) on top of layered deposits—alternating layers of dust and ice accumulated over the martian centuries. A darker field of dunes entirely surrounds the polar cap. At the top are outliers of frost that all lie above a line drawn between 90 and 270 degrees west longitude. The frosted dunes examined in more detail on these pages are marked in small boxes.***



Mars is a sandy world, and dunes are common sights on the floors of impact craters. Compare this image with the image on the cover. Both were taken during the summer, and each image is of an area 25 kilometers (16 miles) across. This crater lies at 78.7 degrees north latitude, 28 degrees west longitude, at the boundary between the layered polar deposits and the circumpolar dune field. The crater shown in the cover image lies at 70.5 degrees north latitude, 257 degrees west longitude, within the region of frost outliers. The crater in this image is defrosted, whereas the crater in the cover image has frost even during the warmest time of the year.



These are close-ups of the defrosted dunes in the image above and the frosted dunes shown on the cover. The dune fields are very similar in size and shape, and the amount of sand is probably similar as well. There is frost apparent in the left image, but mostly around the margin of the field.

The dune sands may remain cooler longer than surrounding rock, and their porosity and permeability may enable them to trap volatiles such as water vapor. But why does frost remain on one dune field but not on the other? There may be differences in the amount of ice trapped or in wind patterns or in dune materials. But none of these differences would explain why all the frost outliers, including the frosted dunes, lie between 90 and 270 degrees west longitude. That's why the behavior of these frosted dunes is an enigma—one that's waiting to be solved by our exploration of Mars.

Information and images courtesy of Michael Malin

Another NEW PLANET: The Excitement Builds

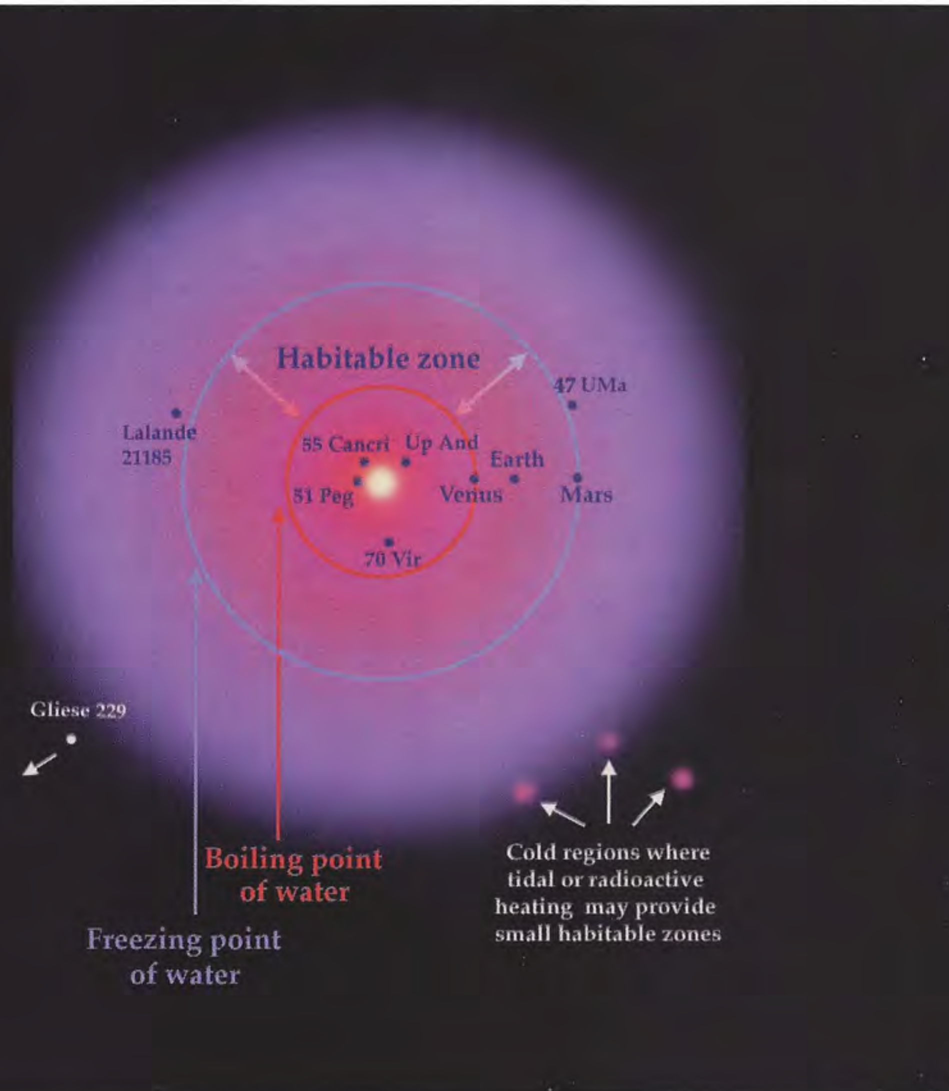
by Charlene M. Anderson

Another new planet found. The e-mail messages announcing such discoveries are in danger of becoming commonplace, and they are now almost expected every few weeks. But the excitement generated by each discovery does not lessen. If anything, the excitement is building, for each new planet increases the probability that the galaxy is swarming with planets, and somewhere out there are worlds like our own—hard, warm, wet surfaces where other life-forms might be flourishing.

New Worlds

Each new planet has challenged our ideas of what planets are and how they should behave. The first extrasolar planets were found where no one expected they could exist—around a fast-spinning pulsar. Many of the new planets have been Jupiter-sized objects in orbits even tighter than Mercury's around our Sun. How such massive objects survive so close to their parent stars is not easy to understand. We've not yet found anything resembling Earth—in fact, we may not be able to detect anything as small and cold as Earth. Nevertheless, each new planet is changing our perception of the universe as revealed through the science of astronomy.

These new planets have also changed the public's focus on astronomy. In the past few decades, most of the journalistic excitement generated by observational astronomy has come from studies of the really big things, such as great walls of galaxies and unimaginably violent supernovas. And the largest institutions and instruments, such as the Keck Observatory and the Hubble Space Telescope, have garnered most of the attention. But this new wave of discovery has returned attention to what we might call a more traditional—and romantic—way of doing science.



Around each Sun-like star is a region called the habitable zone, where liquid water might exist and be available to whatever life-forms might arise on planets in that region. Too close to the star, and water would vaporize; too far away, and it would freeze. Some of the recently discovered extrasolar planets orbit their parent stars within or close to this habitable zone. Here we see the locations of some of those objects, identified by the name of the parent star:

55 Cancri, Gliese 229, Lalande 21185, 51 Pegasi, Upsilon Andromedae, 47 Ursa Majoris and 70 Virginis. Their locations can be compared with those of some more familiar worlds. (Center point represents the star.)

Illustration: Jon Lomberg. Adapted from Worlds Unnumbered: The Search for Extrasolar Planets *by Donald Goldsmith, to be published in January 1997 by University Science Press.*

Many of the successful planet-hunters are coming from smaller observatories that were willing to provide telescope time and modest analytical resources over the long periods of time required for confirming the existence of extrasolar planets. With them, some of the romance has returned to astronomy. Take, for example, George Gatewood of the Allegheny Observatory of the University of Pittsburgh.

Gatewood's name may be familiar to longtime members of The Planetary Society. Back in 1980, our first year of existence, he received the first research grant we ever awarded. Using a relatively small telescope (its aperture was 0.76 meter, or 30 inches, in diameter), he was laboriously tracking the apparent paths of a few well-chosen stars across the sky, seeking any minute wobble that might betray the existence of planets. His research program, built on decades of dedicated observing, was then in danger, and we were able to provide a little seed money to keep it alive.

Astrometry

His technique is called astrometry, and it depends on the fact that a planet does not orbit about the exact center of a star's mass. The star and the planet together orbit a point called the barycenter, which is determined by the ratio of their two masses. The star's motion about the barycenter would cause it to appear to wobble back and forth when viewed from Earth. At the time we awarded Gatewood's grant, this was the most promising technique for detecting extrasolar planets—and perhaps the only technique with a chance of discovering one. The problem was that planets (at least those we know best) can take decades or even centuries to complete one orbit of their star. Planet detection by astrometry is not for the impatient.

Advances in technique have diversified the methods used in planet searches, but astrometry remains a viable tool. And it has succeeded for George Gatewood. In June of 1996, he announced the discovery of the closest extrasolar planet yet confirmed. Its star is Lalande 21185, only 8 light-years away. Although close by, this star is too faint to be seen from Earth without the help of a telescope. The planet is about the size of Jupiter and is about the same distance from its star as Saturn is from the Sun. It takes about 30 years to complete one orbit. Dealing with an orbital period that long, Gatewood used over 60 years of observations from the Allegheny Observatory to confirm its existence.

There is also the hint that another Jupiter-sized object is circling Lalande 21185 at about the distance of our system's asteroid belt, which is between the orbits of Mars and Jupiter. It appears that this planet takes only about six years to complete an orbit. If confirmed, this discovery will make the Lalande 21185 planetary system the most similar yet seen to our own solar system. Life, however, is highly unlikely to have taken hold there. The star is a red dwarf, much fainter than our own Sun, and the planets are too far from it to receive enough light to make life as we know it possible.

More to Come

There are other stories of perseverance and dedication waiting to be told in this search for extrasolar planets. We are now planning a special issue of *The Planetary Report* to give our members an in-depth understanding of this burgeoning new field. The field is close to our hearts, since the search for extraterrestrial life and intelligence has always been a crucial part of The Planetary Society's mission. And life as we know it needs planets to exist. These discoveries bring us closer and closer to achieving that goal. We hope that they continue, and we will do everything in our power to ensure it.

Charlene M. Anderson is The Planetary Society's Director of Publications.

The Origins Program

by Anita M. Sohus

Where do galaxies, stars and planets come from? Are there any worlds like Earth around other nearby stars? If so, are they habitable, and is life present there? What is the origin of the universe?

In January 1996, NASA Administrator Dan Goldin announced the inception of a program called Origins, aimed at seeking the answers to these questions. A number of missions are currently under its umbrella:

First-Generation Missions

- The Hubble Space Telescope (HST), a 2.4-meter reflecting telescope in low Earth orbit.
- The Near-Infrared Camera and Multi-Object Spectrometer (NICMOS), to be added to the HST in early 1997.
- The Wide-Field InfraRed Explorer (WIRE), which will conduct a four-month infrared study of starburst galaxies from low Earth orbit in 1998.
- The Far Ultraviolet Spectroscopic Explorer (FUSE), a spacecraft that will study the origin and evolution of the lightest elements—hydrogen and deuterium—and the processes involved in the evolution of galaxies, stars and planetary systems.
- The Stratospheric Observatory for IR Astronomy (SOFIA), a 2.5-meter optical/infrared telescope mounted in a Boeing 747.
- The Space InfraRed Telescope Facility (SIRTF), an 85-centimeter cryogenically cooled telescope in solar orbit.

Second-Generation Missions

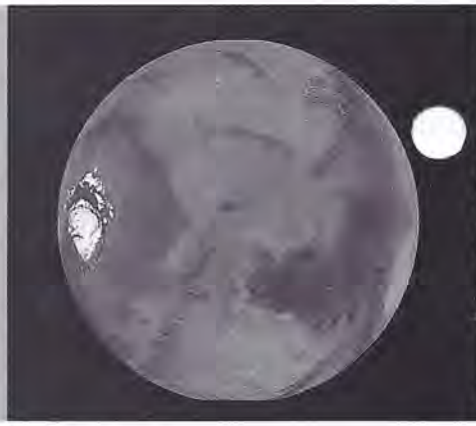
- The Space Interferometry Mission (SIM), a space-based optical interferometer.
- The Next-Generation Space Telescope (NGST), a 4-meter (or larger) space-based telescope.
- The Planet Finder (PF), a space-based optical interferometer that could be launched around 2005 to search for Earth-like planets around nearby stars.

A third-generation mission would be a Planet Mapper. In addition, observations with ground-based telescopes will identify stars with planets by indirect means and will be capable of detecting Jupiter-sized planets. Information on the Origins program is available on-line at this URL: http://www.hq.nasa.gov/office/oss/origins/Origins.html.

Anita Sohus is acting manager of the Outreach and Education Office for Space and Earth Science Programs at the Jet Propulsion Laboratory in Pasadena.

Special Report:

Life on Mars? The Improbable Becomes Possible



by Charlene M. Anderson

Is it truly life from Mars? The electrifying discovery of possible martian fossils in a rock found in Antarctica roused people around the world into wondering about our neighboring planet. Some called it the most exciting space story since the *Apollo* landings on the Moon. And even though Mars exploration is a major thrust of The Planetary Society, the news caught us by surprise. We're now preparing special coverage for a future issue of *The Planetary Report,* but we can detail the evidence presented so far.

The Rock's Story

Some 4.5 billion years ago, during the infancy of the solar system, molten rock beneath the martian crust cooled and crystallized. A rain of comets and asteroids fell on Mars, churning up its surface and exposing our rock to the elements. Then, nearly a billion years later, liquid water flowed across the planet's surface, sustained by a warm, thick, carbon dioxide–rich atmosphere. Some of that water percolated into our rock, filling the fractures within it. Around 3.6 billion years ago, globules of calcium carbonate, the stuff that makes up limestone on Earth, filled some of the cracks. On Earth, at that same time, the first simple bacterial life-forms were beginning to flourish. It may be that on Mars similar organisms were depositing the calcium carbonate in our rock.

Over the next few billion years, Mars' atmosphere thinned and cooled, and liquid water disappeared from the surface. Then, 16 million years ago, a comet or asteroid smacked into Mars and blasted our rock off the planet and onto a course that took it to Earth. Here it fell, 13,000 years ago, onto an ice-covered plain in Antarctica. In 1984, a team from the Smithsonian Institution found the rock and tagged it ALH84001. In 1993, another team, studying its isotopic composition, determined that it had formed on Mars.

Circumstantial Evidence

This determination placed ALH84001 among the select group of 12 meteorites believed to have come from Mars. That alone made it a prime target for investigation. Two years ago, a group led by David McKay of NASA's Johnson Space Center decided to take advantage of newly developed technologies, such as transmission electron spectroscopy, and began to study our rock in the greatest detail possible. What these researchers found is strong circumstantial evidence of past life on Mars.

Within the fractures, they noticed orange-brown globules of carbonate that had been deposited long after the rock itself had formed. These globules were surrounded by bands of dark and white minerals (which they quickly dubbed the Oreo cookie rims). The dark rims were composed of grains of magnetite and pyrrhotite, and within the globules were clusters of magnetite and greigite. These minerals can all be formed by purely physical processes—but not in the same types of environments. The simplest explanation for how they could have been deposited so close together is that they formed as they often do on Earth—within living organisms. In their shape, chemistry and location in carbonate deposits, these minerals more closely resemble biologically produced forms than physically produced ones.

Close by these minerals, the researchers also detected polycyclic aromatic hydrocarbons, called PAHs for short. These organic compounds are found everywhere from interstellar dust grains to the charred residue on backyard barbecues. They have been deposited in the Antarctic via snowmobile exhaust, campfires and other remnants of human presence. But on this Antarctic meteorite, they were found deep within the sample, concentrated near the carbonate globules, and not on the surface. These circumstances indicate that the PAHs are not earthly contaminants but came to Earth within the rock from Mars. In terrestrial rocks, PAHs are common residues of the process that turns microorganisms to fossils.

Finally, the researchers looked at the globules with high-resolution microscopic imaging techniques that have only been developed in the past few years. They saw elongated forms that appeared to be eroded out of the carbonate matrix. Some of the forms looked similar to segmented fossils of bacteria on Earth. The researchers considered three possibilities: (1) The shapes are dried bits of clay. (2) They are contaminants from the Antarctic environment. (3) They are martian microfossils. None of the possibilities can yet be ruled out, but when considered with the magnetite, pyrrhotite and greigite deposits and the PAHs, the third possibility seems the most probable.

But No Smoking Gun

McKay's team has turned in an impressive performance, and its marshalling of the evidence strongly suggests that ALH84001 harbors fossils from Mars. But the evidence remains circumstantial. The team admits this, invites confirmation or refutation by other scientists, and is continuing its work, beginning with searches for amino acids and some indication of cells. Team members are seeking conclusive evidence that these little elongated bits embedded in rock are remnants of ancient martian life.

What form might that evidence take?

Norman Horowitz, professor emeritus at the California Institute of Technology and principal investigator on the pyrolytic-release experiment on the *Viking* landers, has studied the possibility of extraterrestrial life for decades. He is impressed by McKay's team's work and calls it "promising, certainly interesting and done by highly competent people." But, he comments, they "need to do more chemistry." Horowitz would like to see evidence of "amino acids, nucleic acid bases or whatever they can find" that would be indicative of life processes. He also cautions that a rock so ancient is unlikely to yield conclusive evidence of life because such evidence disappears with time.

J. William Schopf, a leading paleobiologist from the University of California, Los Angeles, who has found some of the oldest fossils on Earth, quotes Carl Sagan in his approach to evaluating this work: "Extraordinary claims require extraordinary evidence." Schopf would like to see evidence of cell walls made of carbonaceous material, some indication that there was a population of organisms living within the rock, and examples of cell division or other indications of the life cycle of these putative organisms.

So, there's much more work to be done before anyone can say with certainty that the minute forms in an Antarctic rock are fossils from Mars. But this discovery has pried open the seemingly closed book on martian life. The exploration of the Red Planet has moved to the front pages of the world's newspapers, and The Planetary Society's 16-year advocacy for Mars exploration now seems prescient. The story of Mars has just begun.

Charlene M. Anderson has been editing The Planetary Report *since its inaugural issue in 1980.*

Society News

Scanners for Saturn

Special thanks to the Hewlett-Packard Corporation, which has donated five flatbed scanners for the "Fly your name to Saturn" project. When NASA invited the public to participate in the *Cassini* mission by sending their names along for the ride, postcards with signatures began pouring in. With the new scanners, we are now able to scan many thousands of signatures each week, and the piles of cards in our "*Cassini* Room" seem a lot more manageable.

There is still time to get your signature in. Send us a postcard with your signature (write your name in black ink on the message side of the postcard) and we will scan it and get it over to the Jet Propulsion Laboratory to be included on the CD that will fly to Saturn on *Cassini.*
—Cindy Jalife,
Manager of Program Development

Visit Our Wonderful Web Site

After months of hard work, our new World Wide Web site is now on-line (http://planetary.org/tps/). Our sincerest thanks to everyone who helped pull it all together. Michael Tidmus of Anomalous Research Technologies is the creative force behind the new look; Society members Les Weber of Weber Engineering Associates in North Mankato, Minnesota, and Patrick Roth of Transatlantech Corporation in Ithaca, New York, provide the servers that host the site, which is no small sacrifice given its size—over 550 pages of text and 480 images, making our site a true resource for space exploration on the Internet. A dedicated team of members provided feedback during the reconstruction phase and volunteered to help maintain the site and develop new features in the months to come. Much of the work was made possible by donations from the founding members of our Resource Center. Thanks to all!
—Kari Magee,
Resource Center Manager

A Great Group in Great Britain

Kudos to members of The Planetary Society's volunteer group in England, who did a terrific job orchestrating public events in Greenwich and in Birmingham in mid-July. Led by Andy Lound, they set up outstanding displays at the events, conducted a Red Rover, Red Rover link-up, helped with all of the local logistics and arranged for national news coverage. Thanks to Andy and his team—John Lound, Stuart Williams, Andy Williams, John Lester, Linda and Ken Evans, and Michael and David Horne—for a job very well done. *—Carlos Populus, Volunteer Coordinator*

New UN Status

We've been working with the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) for several years in a consultative capacity, and we have now been given permanent observer status. The notification letter expressed appreciation for the Society's involvement in the committee's activities, one of which is the series of Workshops on Basic Space Science held in developing countries.
—Louis D. Friedman,
Executive Director

Launch Tour Reminder

Call or write us if you are interested in the launch tour for *Mars '96* (in Baikonur, Kazakhstan) on November 10–20, 1996; or for Mars *Global Surveyor* (Cape Canaveral, Florida) on November 2–9. Space is limited—and these are special. *—Susan Lendroth, Manager of Events and Communications*

Rover Conference

The 1997 International Conference on Mobile Planetary Robots and Rover Roundup will be held in Santa Monica, California, January 29 through February 1, 1997. For details, call us at 818-793-5100, or e-mail us (tps@genie.com).
—SL

More News

The Mars Underground News:
Updates on Mars missions…the Planet-B orbiter…images of Mars.
The Bioastronomy News:
Special report from Capri, Italy, on the 5th international symposium on bioastronomy.
The NEO News:
The progress of the Near-Earth Asteroid Rendezvous…Hyakutake…computerized asteroid detection.

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

Robots Versus Humans: The Next Space Race?

by Louis D. Friedman

I have adapted this essay from talks I've given this year at the American Association for the Advancement of Science meeting in February, the International Space Development Conference in May and a public talk in Great Britain in July. It is a work in progress—I am developing a viewpoint about the human role in planetary exploration. I welcome comments.—LDF

In talks all over the world, I have been describing the great space race we are engaged in. The outcome will determine the very future of civilization, and the survival of our species. It is a race we must win to prove the superiority of our way of life.

This rhetoric may sound like something left over from the time when the United States raced the Soviets to the Moon. But I am describing another race: the competition between humans and robots to explore the planets.

At a Society lecture in the early 1980s, Laurel Wilkening (now a Planetary Society Director) said that it is not a question of whether we will explore Mars; it is only a question of what language the explorers will speak. She was referring to English, Russian, Japanese, Chinese, French—but I now modify this to include another possibility: the binary language of ones and zeros.

In the 1960s, in an effort unparalleled in human achievement, we traveled to the Moon. Then, catching our breath for a few decades, we returned to low Earth orbit. Now, in the next few years, once the international space station takes shape in Earth orbit and the several Mars spacecraft send data home, interest in space exploration will grow. We are learning to cope with the rigors of long-duration space travel; an American astronaut on *Mir* has broken the US endurance-in-space record. We are on the cusp of new knowledge about the relationship of humans to the universe.

But our robotic technology is developing even faster. Miniaturization of systems and the advances in information processing manifested in telerobotics and virtual reality may eliminate the need for a human presence in exploration, except at the receiving end. Imagine a thousand microrovers at a thousand sites on Mars, supported by a hundred balloons, each transmitting tens of megabits per day. We could supply every human on Earth with a virtual reality experience of exploring Mars that will exceed the capacity of any astronaut. It may be a lot cheaper, too.

Where Will We Be in 2196?

I cannot imagine where robotic technology will be in, say, 2196—or even in 2096. But neither can I imagine where our species will be. Genetic knowledge and control are moving just as fast, and the implications are more inscrutable. This is what I mean by a space race that will determine our existence: Will Mars be explored and settled by human colonists taking a step in evolution toward becoming a multi-planet species? Or will it be explored by a bunch of couch potatoes at home, with bubble-rooms re-creating the Mars environment through holographic projections built from the data gleaned by robotic probes?

Of course, my description of a human versus robot space race is polemical—I am trying to provoke opinions about the course of human spaceflight in the context of our current programs in space exploration. The human space programs of the world have effectively merged—working toward one goal together, the space station, the largest international engineering project in history. American astronauts are again flying long missions. And our robots are going back to the Moon, to Mars and to a near-Earth asteroid. We are discovering extrasolar planets, and we are poised to gather new information about possibilities for life beyond our world. In 1997, three missions will fly to Mars; one spacecraft will visit the Moon; *Galileo* will have finished mapping four worlds, plus examining Jupiter itself; the number of extrasolar planets discovered will probably have doubled; and, believe it or not, space station hardware—American and Russian—will be orbiting Earth! If this comes to pass, you can bet cover stories in *Time, Der Spiegel, Match* and other magazines will ask, "Where are we going in space?"

The correct path to the planets seems clear: We should explore the Moon first. And we have. One dozen astronauts went there, in six missions, accompanied by several dozen spacecraft and supporting missions. What next? The choices now are more of the Moon, small near-Earth objects (asteroids), Mars, or just hanging out in some space structure in low Earth orbit. Or nowhere.

The answer to "where next?" depends in large part on technical feasibility and on political rationale. Since *Apollo*, which was barely technically feasible but strongly supported politically, those two conditions have not come together to provide an answer.

Sending humans back to the Moon is clearly feasible, but the rationale is lacking. Lunar flights were discounted with good reason—nothing was left to do there except science, and science can be done more cheaply without humans. Jack Schmitt was the first lunar scientist, and the last lunar explorer. There have been countless symposia and conferences on "back to the Moon" (the very phrase denotes it as a backward step), but none have ever come up with a rationale that couldn't be done cheaper, faster and better with telerobotics, or with only occasional human visits.

What Can We Do on the Moon?

This does bring up what we can and should do at the Moon, and that is telerobotics. The Moon is a wonderful place to advance it, apply it and test it. Many wild ideas of amusement park applications and virtual reality games have been added to the astronomical and scientific possibilities, and all need reliable, interesting and exciting telerobotics. The recent Japanese space policy pronouncement of a lunar robotics goal, the European endorsement of lunar missions, NASA's selection of the *Lunar Prospector* mission, all bode well for stimulating lunar telerobotics. But before the enthusiasts get too excited, they had better understand that they will have to prove themselves economically. All of the lunar ideas must have either a cost-effective scientific justification or an economic return for their investors. For a while, both of these factors are likely to be low.

Mars is an obvious choice. Every (and I mean *every*) consideration of where human spaceflight is heading ends up at Mars, sometimes quickly (in 10 years), sometimes slowly (in 20 or 30 years). Mars is the only known world (besides our own) where we can imagine past life taking hold or future life settling down. Even that is a stretch—Mars is a lot more hostile than the deep sea floor or the Antarctic continent, neither of which we have settled. But Mars is the best destination we have off this planet, and it will be for as long as we can see into the future. Uniquely in our solar system, it has accessible oxygen, water and warmth. Mars is, I believe, the place where the extraterrestrial destiny of the human species will be determined.

If we fail to start on Mars settlement in the next century, that will be a negative statement about our species' outward thrust: We can, but we won't. Conversely, if we do begin to settle Mars, it bodes well for the idea of human life spreading throughout the galaxy.

A lot is happening now to get ready for Mars. The *Pathfinder* and *Surveyor* missions in the US, *Mars '96* and the Mars Rover in Russia, and Japan's Planet-B mission will all be flying soon. The US has approved a Mars program with two launches to Mars at every opportunity. This marks, for the first time ever, a commitment to systematically explore another world. The Gore–Chernomyrdin meeting has endorsed Mars Together and joint planning for a Mars sample return in 2005. There is now an opportunity to make that mission a true international effort, with Europe and Japan taking part.

Going for the Whole Enchilada

What will be next? If it were up to me today, I'd go for the whole enchilada. I agree with Robert Zubrin's notion of Mars Direct (see the September/October 1992 *Planetary Report*) and believe that we can do it cheaper, faster and better. We could commit to the mission in 2005 and launch by 2013. Note that inherent in this concept are robotic, science and engineering precursor missions.

But it isn't up to me, and maybe that isn't the best idea anyway. There is the huge problem, recognized by NASA, of launch vehicles. We have neither inexpensive boosters nor any that are capable of launching humans out of Earth orbit. Russia is abandoning the *Energia*, just as the US abandoned the *Saturn 5*, and it is hard for me to see the solution. The *X-33* (the reusable launch vehicle development project just initiated) may lead to a solution of the booster problem, probably not soon.

There is also a possible diversion on the path to Mars—that swarm of objects in which Earth exists, the near-Earth objects, or NEOs. They could be stepping-stones for humans into the solar system. They are fascinating objects to explore, and the Near-Earth Asteroid Rendezvous (NEAR) spacecraft now flying to Eros, and the Nereus sample return mission (Muses-C) now being planned will only whet our appetites for more. NEOs are particularly relevant to that basic human desire to understand our relationship to the universe. Impacts from NEOs have profoundly influenced Earth's evolution in the past, and without doubt will do so in the future.

Steve Ostro and Eric de Jong at the Jet Propulsion Laboratory have made a number of beautiful computer movies about the gravitational fields and shapes of these objects. Watching them, you know how much fun it would be for humans to explore them in person. I suspect that the NEOs are going to be telerobotically explored, but I am willing to have my mind changed as we think about the best way to Mars.

Space budgets are declining for NASA, the Russian Space Agency and other countries. Probably, shortsightedness will win the day and inhibit the possible. But despite that, I revel in the progress being made now. The Hubble Space Telescope, *Galileo*, NEAR, *Pathfinder*, *Surveyor*, *Mars '96*, *Prospector*, Lunar-A, *Cassini/Huygens*, Mars Together, Planet-B, the New Millennium, the Mars Rover, sample returns, shuttle–*Mir*, the space station—we humans are on the way to Mars. We are looking for ourselves in the universe, to understand the possibilities for life and for intelligence. It is a quest only for optimists and, being one, I think we humans will win the space race.

Society Executive Director Louis D. Friedman is definitely not a couch potato and spends much of his time traveling and speaking about Mars and the importance of planetary exploration.

Society Sponsors Space Research in the Third World

by Duncan Steel

Members of The Planetary Society will realize, and appreciate, that the Society is extremely judicious in allocating funds to different projects. The pages of this magazine carry discussions of very expensive programs run by large-budget space agencies, these being of interest to Society members, but reports are also carried on smaller projects with modest funding requirements, where small injections of funding can bring about major returns. These might be projects proposed by small groups at universities or other research institutions, in the United States or elsewhere in the developed nations, but there are also many able, enthusiastic—and even ambitious—explorers of the solar system living in countries that have only rudimentary facilities available, and practically no research funding.

Recognizing this, the United Nations (UN) and the European Space Agency (ESA) have since 1991 been organizing an annual Workshop on Basic Space Science, which focuses on planetary exploration and astronomy in the developing nations. The Planetary Society has been proud to be a sponsor of these meetings, which are aimed at bringing together scientists from third-world countries and also enabling them to meet researchers from the modernized nations.

In January 1996, the workshop was held in Sri Lanka, an unusual but exciting place for any science conference—especially if it is held in 1996 and yet is claimed to be the annual meeting for 1995. In the melting pot of the Indian subcontinent, such things are almost commonplace, and in this case easily understood: The annual workshop for 1995 was scheduled for November of that year in Pakistan but troubles in that country led to a hasty reorganization, Sri Lanka stepping in to fill the breach with an offer to host the meeting in January 1996. That this was possible was no doubt due at least in part to one of Sri Lanka's most famous residents being Arthur C. Clarke, writer of *2001: A Space Odyssey* and numerous other science fiction and science fact books, inventor of the synchronous communications satellite concept and a member of the Board of Advisors of The Planetary Society.

Clarke's involvement did not end there. Some years back, when he was awarded the Marconi Prize for his work in radio communications, he donated the prize money so as to found the Arthur C. Clarke Centre for Modern Technologies, which is associated with the University of Moratuwa; Clarke is the chancellor of that university, one of several in Colombo, Sri Lanka's capital and his longtime home. Now the Arthur C. Clarke Centre was to take on the load of the local organization for this conference, felicitously meshing with the donation to the Centre of a 46-centimeter-diameter (18-inch) telescope by the government of Japan. Indeed, the theme adopted for the meeting was the space science that can be done with small telescopes, defined as those with apertures smaller than 1 meter (about 3 feet) in diameter.

Previous workshop meetings had been in India in 1991, jointly in Costa Rica and Colombia in 1992, in Nigeria in 1993, and in Egypt in 1994. The conference originally scheduled for 1996 will be held in Bonn, Germany, in September, bringing it for once close to the main center of organization, the UN Office for Outer Space Affairs in Vienna, Austria. The Sri Lanka meeting carried on the tradition of bringing together scientists from a wide range of technologically developing countries, like Malaysia, Oman, Indonesia, Honduras, Vietnam, Thailand and Morocco, along with scientists from the US and Europe.

Too many disparate subjects were discussed for a complete description here, but author's prerogative permits me to mention that presentations by Tom Gehrels (University of Arizona) and myself enabled us to describe the current efforts in searching out Earth-approaching asteroids and comets, and to invite astronomers in smaller countries to get involved in such work. Two reports to the US Congress in the past few years have recommended a global program—to be called Spaceguard from a fictional project described by Arthur C. Clarke in 1973—that would be aimed at finding all such objects and determining their orbits with sufficient accuracy for any calamitous terrestrial impact within the next century to be foreseen and the potential impactor intercepted.

The Planetary Society is a sponsor of a similar program, which is conducted by Eleanor Helin at the Jet Propulsion Laboratory. In Europe, there is a greatly enhanced interest in this topic, and the Spaceguard Foundation has been established in Rome, with Gene Shoemaker (Lowell Observatory, Flagstaff, Arizona), Brian Marsden (Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts) and myself as three of the directors, along with Andrea Carusi (Rome), Syuzo Isobe (Tokyo) and Karri Muinonen (Helsinki).

In order to carry out such a sky-scanning program, a wide geographical spread of search and follow-up telescopes is required, and instruments of all apertures can make a vital contribution. It's just the sort of space project that smaller nations with poor economies can get involved in, as demonstrated by the enthusiasm with which the talks by Gehrels and myself were greeted. And it's also another example of how your membership fees enable The Planetary Society to spread the word around the globe so that one day we may spread out into the rest of the cosmos.

Duncan Steel works at the University of Adelaide, South Australia, where he directs the Australian program of search and tracking of near-Earth objects, and also uses various radars to study meteor trails in the atmosphere.

News and Reviews

by Clark R. Chapman

"Life on Mars!" The headline has been written before. Early in this century, Percival Lowell used the best astronomical detector then available—the human eye—to study the Red Planet. Unfortunately, his psyche intervened and distorted his retinal images into fantastic views of a planet crisscrossed by the works of intelligent canal-builders.

In the 1950s, astronomical spectroscopy yielded a false report that martian spectra showed the signature of chlorophyll. An early *Mariner* Mars probe returned pictures of a cratered Moon-like landscape; *The New York Times* editorialized that Mars was dead. Later *Mariners* and *Vikings* yielded conflicting evidence that sometimes enhanced, sometimes dashed, hopes that life might have thrived on Mars during an earlier, more clement epoch.

The world was not waiting for an answer this year to the question of whether there is life on Mars. No new-technology telescopes have been observing Mars. No spacecraft mission has successfully reached Mars since the *Vikings* two decades ago. Who would have thought that the answer would come from the ice fields of Antarctica? (For more on the NASA announcement that researchers may have found evidence of life on Mars, see page 14.) During the long lull in the space program—with no more astronaut-returned Moon rocks and no NASA commitment to a post-*Viking* Mars sample-return mission—cosmochemists continued to do what research they could. Antarctic meteorites provided the richest lode of extraterrestrial materials for them to study with their ever more sophisticated laboratory instruments. Finally, hard work and ingenuity paid off. Or so it seems.

The quest to resolve whether or not we are alone has led to many premature answers besides Percival Lowell's. In recent years, the public was confused by repeated announcements (followed by retractions) of planets around other stars. One of the Holy Grails of astronomy has been to find other planets, and the underlying motivation is the same as the focus of the public's interest in Mars: to find potential abodes for extraterrestrial life.

During the past year, the premature findings gave way to solid evidence for extrasolar planets, but none yet that are truly Earth-like. Even discovery of potential life-sustaining planets would not stir the public imagination so profoundly as the discovery of extraterrestrial life itself, even primitive, fossilized life. Still more central, of course, would be the discovery of alien life-forms living today, an intelligent message from the stars—or an extraterrestrial visitation.

Finding alien life of any sort represents an enormous leap from the alternative possibility that Earth is utterly unique in the universe as an abode for life. That life seems to have existed on such an accessible neighboring world is enticing, indeed. Even before the Johnson Space Center (JSC) announcement, plans were under way to develop Mars missions that might explore the most likely refugia, beneath the surface of the Red Planet, where life-forms—retrenched from an earlier, warmer, wetter climate—might still be living. The very real possibility of exploring Mars for signs of life is the reason many leaders of the American scientific establishment attended the historic NASA news conference. And it's why President Clinton himself chimed in with a next-to-the-helicopter statement.

The findings were published in August in *Science* magazine. They still face their most daunting test: acceptance by the wider scientific community. Most articles submitted to *Science* are refereed (read critically) by only one or two experts before being accepted for publication. No doubt others were consulted before NASA orchestrated its high-profile announcement and before the nation's chief science agency heads would dare to endorse the research. But I heard no rumors of the Mars findings at the July meeting in Berlin of the world's major scientific society devoted to studying extraterrestrial materials, the Meteoritical Society. Most would-be critics of the research were unaware of it, let alone the details, before NASA's surprise announcement on August 6th. In the next year we will learn if the results stand up to penetrating scrutiny by the world's research community.

Whatever the judgment, I expect that NASA's space program will be forever changed. Perhaps the agency will soon be shown to have fallen on its face again, as in the Hubble Space Telescope mirror fiasco. We can all hope, however, that the careful work of the experienced Mars rock researchers will withstand the inevitable attacks by skeptics, and there will be a genuine reason to broaden our endeavors in the new field of astrobiology.

Not only must we go to Mars to confirm and expand the martian-meteorite evidence. After all, an Earth-born meteorite could have "infected" Mars. A more remote, but still accessible, potential abode for life is Jupiter's second moon, Europa. The *Galileo* orbiter is searching for evidence that a global ocean of water might lie beneath that world's icy crust; Europa is probably the only other potential Earth-like environment in the solar system besides hydrothermal regions on Mars. NASA may soon decide to extend *Galileo*'s nominal two-year mission to focus on Europa and its hypothesized life-sustaining ocean.

Beyond Europa and our own solar system lie the other stars. I forecast a renewed push to search for Earth-like (or Mars-like) planets elsewhere. If life can be independently generated on a second planet in our own solar system, the potential habitable zones around other stars are more expansive than had been theorized. And maybe Congress will stop laughing at the serious attempts of SETI researchers to listen for intelligent radio signals from the cosmos.

Clark R. Chapman and his wife, Lynda, have been hiking in the Rockies lately — since their move to Boulder from Tucson — and loving it!

Questions and Answers

Is it possible that somewhere out there is a star that failed to ignite and it is now going through space complete with a planetary system? Would we be able to detect it?
—William Biewener, Glendale, California

The theory of stellar structure tells us that objects having less than 8 percent of the mass of the Sun (brown dwarfs) will fail to ignite but will nonetheless become luminous and remain so for about 100 million years as they contract from a gaseous nebula and release their gravitational binding energy. A few brown dwarfs have recently been discovered in the nearby Pleiades star cluster. However, these objects are so faint that it would be impossible, using current technology, to determine whether or not they have planets.

There is another approach to detecting brown dwarfs that could reveal their planets: gravitational microlensing. If a brown dwarf (or any other object such as a star or a black hole) were closely aligned with a more distant luminous star (say in the central bulge of the Milky Way), its gravity would split the star's light into two images separated by about 1/10,000 of a second of arc. This is called gravitational lensing. (One second of arc is 1/3,600 of a degree—the size of a dime seen at 2 miles distance.) This tiny angle is too small to be resolved even with the Hubble Space Telescope, but the combined light of the two images would be greater than the normal light from the star. Hence, as the brown dwarf moved closer to and then farther away from the line of sight to the star, the star would appear to become brighter and then fainter. The larger the mass of the brown dwarf, the longer the time the microlensing event would last.

Four groups of scientists are currently monitoring millions of bulge stars and have found more than 100 events. Unfortunately, it is not possible to measure the mass of any given lensing object (whether brown dwarf or star) from the timescale alone because the object's velocity and distance also affect the duration of the event. Statistically, however, there appear to be far too many short events to be accounted for by known populations of stars, so some events could be due to brown dwarfs.

If one of the lensing objects had a planet, and if this planet happened to align with the light path of one of the two images of the bulge star, then it would perturb the image and cause a change in the magnification. The square of the duration of this perturbation relative to the overall timescale of the event would tell us the ratio of the planet's mass to the mass of its parent star or brown dwarf.

Scientists believe that brown dwarfs—dim bodies too small to be stars yet too massive to be planets—could be significant contributors to our galaxy's "missing mass." But, until recently, these substellar objects have been impossible to find. Their number remains a mystery. This painting depicts Gliese 229, a red dwarf star in our own galactic neighborhood (19 light-years away). The dark body in orbit around the star is Gliese 229B, an object that many scientists think qualifies as the first undeniable brown dwarf detected.

Painting: David Egge

For Earth- to Jupiter-sized planets, the perturbation would last a few hours to a day. Two groups of scientists are currently using worldwide networks of telescopes to monitor continuing lensing events around the clock in order to search for planetary companions of the lensing objects.

To determine whether a detected planet is orbiting a brown dwarf or an ordinary star, it would be necessary to determine the mass of the lensing object, and this would require additional information over and above the timescale. One way to obtain such information would be to put a small telescope in solar orbit. When the brown dwarf was most closely aligned with the star as seen from Earth, it would have not yet reached (or already passed) the point of closest approach as seen from the telescope. The telescope would therefore see a different amount of magnification than would an Earth-based observer. The difference could be used (together with other data obtained from Earth) to triangulate the event and so determine the distance and mass of the lensing object. Such a telescope has been proposed but has not so far been approved.

Thus, it is certainly possible to detect planetary systems even when their central objects are faint brown dwarfs, and this may in fact be done in the next few years. Confirming that the central object is a brown dwarf would require a bit more work, but it may be possible in the next decade or two.
—ANDREW GOULD,
Ohio State University

News reports on comet Hyakutake varied in their details. The comet's period seemed to range from 8,000 to 20,000 years. Is this because we were seeing the comet near perihelion, where it is difficult to distinguish its orbit?

How far out will Hyakutake go before it turns around and heads back in? Will it go out to the Oort cloud? Not quite that far? Somewhere else?
—Blan Shattuck,
Potomac, Maryland

Because the elliptical orbit of comet Hyakutake is so large and the comet has been observed for only a small portion of this path, it is very difficult to accurately determine the size of its orbit or its orbital period. It's a bit like trying to determine the size and shape of the Indianapolis Motor Speedway by observing only a few feet of it. In addition, because of the gravitational tugs due to the solar system's planets, the size and shape of the comet's orbit are constantly changing.

As a result, the interval between this past visit and the comet's last return to the solar neighborhood was approximately 17,000 years, but it will be another 64,000 years before Hyakutake returns. The comet's farthest point from the Sun (aphelion) was 1,314 astronomical units (AU) before it recently entered the inner solar system, and before it returns again it will reach an aphelion point of 3,190 AU. One AU is the mean distance between the Sun and Earth or about 150 million kilometers (93 million miles).

These are great distances but still well inside the central region of the Oort cloud (50,000 AU) at the outer edge of our solar system.
—DONALD K. YEOMANS,
Jet Propulsion Laboratory

A news report I read says that water inside martian meteorites found on Earth shows that the Red Planet is wetter than previously thought, making it more likely that life once existed there.

How do scientists know that the meteorites came from Mars?
—Ronald J. Hickes,
Stone Mountain, Georgia

Evidence from isotopes trapped in these meteorites strongly suggests their martian origin, because of similarity with known properties of the martian atmosphere as measured by the *Viking* spacecraft.

These meteorites contain small amounts of water whose oxygen isotope ratios differ from those of water on Earth, and they also contain minerals diagnostic of exposure to water. Taken together, these bits of evidence suggest not only that the meteorites came from Mars but also that Mars was once a more watery planet.

The martian meteorites are believed to have been ejected from Mars by meteorite impacts, after which they traveled for perhaps millions of years in interplanetary space before arriving at Earth. (See page 14 for more on life on Mars.)
—JAMES D. BURKE,
Technical Editor

Factinos

Io, Jupiter's innermost satellite, probably has an iron core, just like Earth, according to data gathered by the *Galileo* spacecraft during its flyby of the moon on December 7, 1995.

Scientists used radio waves to measure Io's gravitational field, allowing them to determine how Io's mass is distributed and to create a model for its interior. The study was led by John D. Anderson and William Sjogren of the Jet Propulsion Laboratory, with Gerald Schubert of the University of California, Los Angeles.

Io specialist Alfred McEwen, a geologist with the United States Geological Survey in Flagstaff, said, "It's a nice result. We didn't expect to get useful gravity data from the flyby, but the engineers as usual proved more clever than they themselves predicted. It was expected that Io would have an iron core. We didn't have any measurements that could directly confirm this until now."
—from Jane E. Allen in the Pasadena *Star News*

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Scientists have shown that precursors to biological molecules form when simple organic compounds are blended and cooked. Yet these prebiotic molecules rarely combine into chains of more than 10 to 20 links. To replicate, researchers believe, molecules must contain close to 60 molecular segments—the minimum necessary to sustain a primitive genetic code.

Now James W. Ferris, a chemist at Rensselaer Polytechnic Institute in Troy, New York, and his colleagues have shown that long, chainlike molecules called oligomers can assemble themselves on mineral surfaces. Ferris' team mimicked conditions in which a warm broth of prebiotic molecules repeatedly splashed up on rocks and dried in the Sun. The scientists poured solutions of amino acids and nucleotides over each of three materials: a clay known as montmorillonite and two porous, bonelike materials called illite and hydroxyapatite. Oligomers up to 55 units long were produced after many cycles of incubation, evaporation and replenishment. The group described the chemical feat in the May 2 issue of *Nature*.

If organic molecules solidified on warm stone, says Günter von Kiedrowski of the University of Ruhr in Germany, "the polymers of life were more likely to have been baked like prebiotic crepes than cooked in a prebiotic soup." In a commentary accompanying the report in *Nature*, he added, "The message is that the earliest forms of life may have proliferated by spreading on surfaces."
—from R. Lipkin in *Science News*

Basics of Spaceflight: Thermal Control

by Dave Doody

If your computer gets too hot, it will probably experience a failure before long. Chances are it has a fan to keep its circuits from overheating. Or at least it has vents, placed in key locations, so that the air can flow around inside it, driven by convection: Air inside the computer, heated by the warm electronics, expands, becoming less dense than the cooler air outside. The denser, cooler air flows in to replace the warm, which ends up bubbling out the top, not unlike the behavior of bubbles in boiling water. As a result, heat is transported away from the computer's interior, keeping it cool.

If you look inside your computer (or television, or audio equipment), you'll see that some of the chips, the ones that generate the most heat, have metal fins attached to them. This reveals another basic method of transporting heat: conduction. The base of each fin conducts heat away from the attached chip and carries it first to the relatively larger surface area of the fin and then into the adjacent air. Air blown by the fan carries the heat away; if there's no fan, convection takes over to transport the heat. Conduction is responsible for an iron frying pan's handle getting too hot to touch. A good conductor, such as iron and many other metals, transports heat from one molecule to the next. An insulator has the opposite property: Heat encounters difficulty flowing from one point to another within it. An example would be a thick glove, or a blanket.

Cooling in the Absence of Air

But how about the computers aboard an interplanetary spacecraft? You can't just run a fan, because there's no air for the fan to blow. And without air or some other fluid, you can't depend on convection to keep things cool. In this installment, we'll take a look at the thermal control system found in US interplanetary spacecraft.

Thank goodness for radiation, which is the process that allows a spacecraft to get rid of its excess heat. You've undoubtedly experienced heat radiation when standing near a fire in a fireplace. While convection carries much of the fire's heat up the chimney (conveniently carrying away smoke and soot with it), the fire also radiates—that is, sends out—both visible light and infrared light in all directions at the speed of light. It's that infrared radiation you feel on your skin as heat while standing beside the fire.

Infrared (*infra-red,* meaning "lower than red light"—that is, lower frequency) is just light whose wavelength is too long for our eyes to detect. (See the January/February 1996 *Planetary Report.*) Unlike convection or conduction, radiation doesn't depend on air or any other medium to help it operate. It just propagates through empty space the way light or any other electromagnetic radiation does. That's how the Sun's heat gets to Earth.

A spacecraft has to be carefully designed to best use the principle of radiation, since that is the only avenue that allows its excess heat energy to be carried away into the vacuum of space. Heat radiation, or infrared radiation, is also called thermal radiation.

The Color Connection

In dealing with thermal radiation, a spacecraft can take advantage of related effects, absorption and reflection. You probably know from experience that hot black pavement can absorb enough of the Sun's thermal radiation to fry an egg. But your poor bare feet can find some comfort if you walk on the white lines in the pavement. They're cooler because they reflect a lot of the thermal radiation they encounter. *Magellan* operated in orbit around Venus, which is much closer to the hot Sun than Earth is. So, of course, most of *Magellan*'s external surfaces were colored white (or gold), to reflect as much of the infrared radiation as possible. White was the color of the outer layer of blankets covering most of *Magellan*. These blankets were designed to minimize the conduction of heat in toward the spacecraft. Such "thermal blankets" are important components of most spacecraft's thermal control systems. Since they minimize the conduction of heat, they are also helpful in keeping spacecraft warm when they are far from the Sun. By the way, blankets on your bed do that, too: They minimize the conduction and convection of your body's heat into the cold surroundings. The ones on a spacecraft perform an additional function, though, which is probably not needed in your bed. They stop tiny meteoroids from crashing into the spacecraft's equipment.

Magellan's solar panels could not be painted white, because they needed to absorb sunlight to produce electricity (see the July/August 1996 installment of this column). So the panels were carefully designed to minimize the heat they collected. Rows of silicon solar cells were alternated with rows of quartz mirrors called optical solar reflectors. The cells were cemented to the panels with a thermally conductive glue, so that heat could be conducted to the back side of the panels, and from there radiate away into space.

Optimizing Operations

The way a spacecraft is operated can also be part of its thermal control. *Magellan* was sometimes commanded to point toward the Sun, so that its large, white antenna dish would shade the rest of the spacecraft for a while, reducing its absorption of thermal energy. This allowed the spacecraft to experience a net cooling effect as some of its heat continued to radiate away into space.

Galileo, in contrast to *Magellan,* is mostly black, since it was designed to operate in Jupiter orbit, far from the Sun's hot radiation. Its black color allows it to absorb what infrared energy it can to keep things from getting too cold to operate. To get to Jupiter, though, *Galileo* had to loop around the inner solar

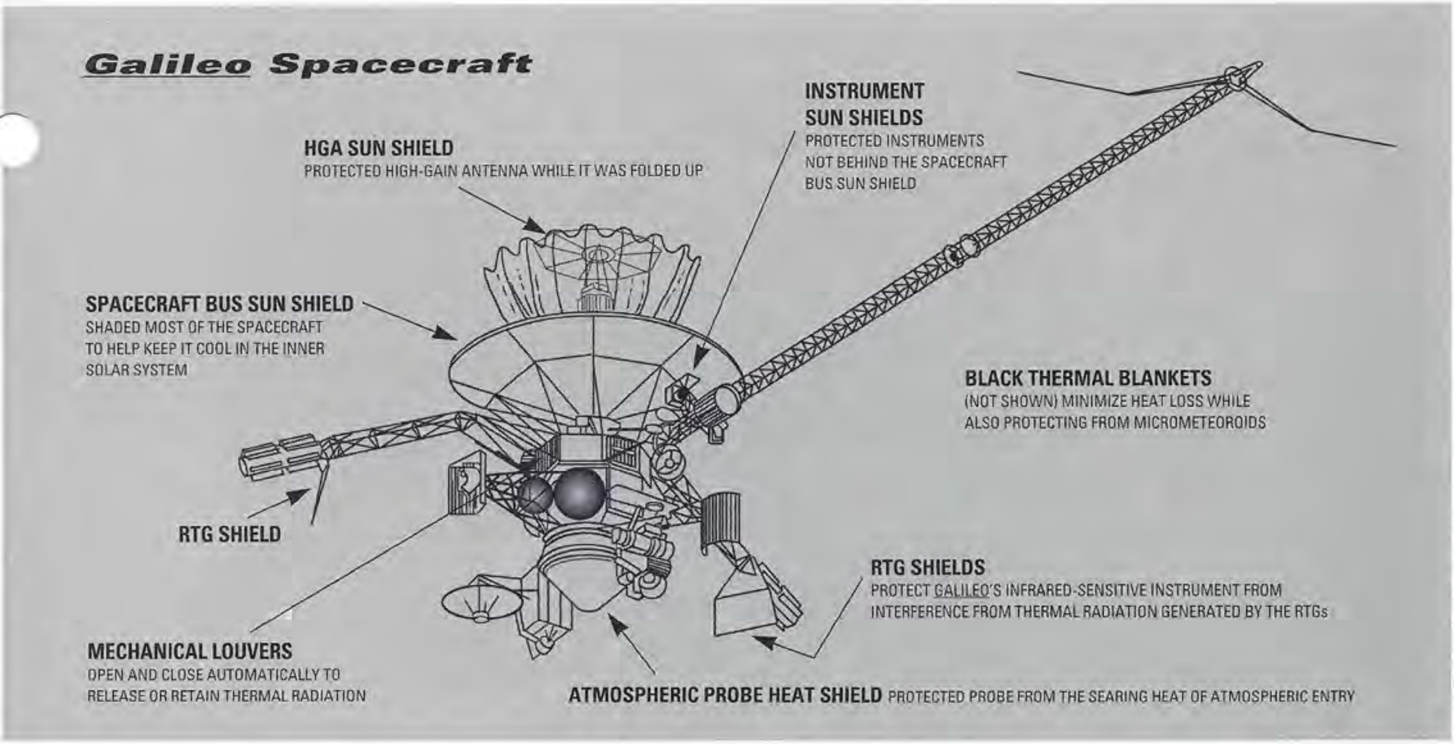

CHART BY DAVE DOODY; REDRAWN BY B.S.SMITH

system for the better part of three years, executing gravity assists to gain speed (see the May/June 1995 *Planetary Report*).

During its entire flight in the inner solar system, *Galileo* was operated in such a way that always kept it pointing directly toward the Sun. That way, *Galileo*'s built-in sunshades kept the Sun's hot thermal radiation off most of the spacecraft. Now that *Galileo* is orbiting Jupiter, it keeps warm partly by passive means, that is, the black external color, and the effect of its thermal blankets.

Turning Up the Heat

Galileo, as do other interplanetary spacecraft, also uses active means to keep warm. Electric heaters installed in various locations operate under control of the command computer, based on temperature measurements and commands from Earth. Many onboard instruments have electric "replacement" heaters. When an instrument is operating, it normally produces enough heat of its own. When the instrument is turned off, a replacement heater may be turned on to prevent the instrument's components from getting cold enough to sustain damage. Radioisotope heater units are also installed in specific locations on *Galileo*. They generate their own heat from the decay of radioactive elements, and warm their surroundings via conduction and thermal radiation.

In the vacuum of space, things can get too hot or too cold no matter what their distance from the Sun. *Magellan*, close to the Sun, had electric heaters to warm components that cooled in the shade. *Galileo*, far from the Sun, has ways of getting rid of excess heat. If you look closely at *Galileo*, *Voyager* or most any other interplanetary spacecraft, you'll see shiny metal louvers, much like venetian blinds or the adjustable glass louvers found on windows in one's home. But in the depths of interplanetary space, there's no air to let in!

Then why does a spacecraft have louvers? To control thermal radiation from the spacecraft's interior. If it's too warm inside the spacecraft, the louvers open, and the thermal energy (heat) can radiate out into space. If it's too cool inside, the louvers shut, and the heat radiating inside the spacecraft gets reflected back by the polished inside surfaces of the closed louvers. Since the infrared radiation doesn't escape, it keeps the spacecraft warm inside.

The louvers are controlled mechanically, with coiled bimetallic strips similar to the one you'll see inside the thermostat on your wall. (Place two strips of different metals alongside each other, and connect them at each end. Since the metals are different, they will expand and contract at different rates when heated or cooled. This will cause the pair to curl one way or another as the temperature changes.)

Let's consider another thermal problem: interference. Some scientific instruments on a spacecraft are sensitive in the infrared region of the spectrum so they can measure a planet's temperature and take spectral readings. These instruments must be shielded from anything on the spacecraft that radiates heat (infrared energy), lest it interfere with the instrument's observations. On *Galileo*, you'll see a shield below each of its RTGs (radioisotope thermoelectric generators; see the July/August 1996 *Planetary Report*). These sources of electrical power are hot, and their thermal radiation might interfere with *Galileo*'s sensitive near-infrared mapping spectrometer instrument, but for the RTG shields.

Another Kind of Shield

Atmospheric probe spacecraft, such as *Galileo*'s probe, and *Huygens*, the Titan probe carried by *Cassini*, must be able to withstand the fiery heat of high-speed entry. Friction with Titan's upper atmosphere will produce temperatures around 12,000 degrees Celsius (roughly 22,000 degrees Fahrenheit) in front of *Huygens*' heat shield, which is made of silica-fiber tiles. Just centimeters away, behind the insulating shield, the structure will barely reach 150 degrees Celsius (about 300 degrees Fahrenheit).

In the next issue, we'll visit the question, "Who is at the helm?" Who pilots *Voyager*, *Galileo* and other interplanetary spacecraft?

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/.

We are at the beginning of a new age of discovery as announcements of newly detected planets around other stars become less surprising and more exciting. Christina Wioch's painting "Journey Towards the Light" depicts a hypothetical planetary landscape. In the distance we see the vivid pink of hydrogen gas clouds, and in the foreground, a frozen nitrogen lake. "When I did this painting," Christina says, "my goal was to create something with strong color, depth and multiple meanings."

Christina Wioch's space art has been displayed at NASA's Ames Research Center and at the Jet Propulsion Laboratory. She is also a member of the Guild of Natural Science Illustrators and her work has appeared in numerous publications for the National Park Service.

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