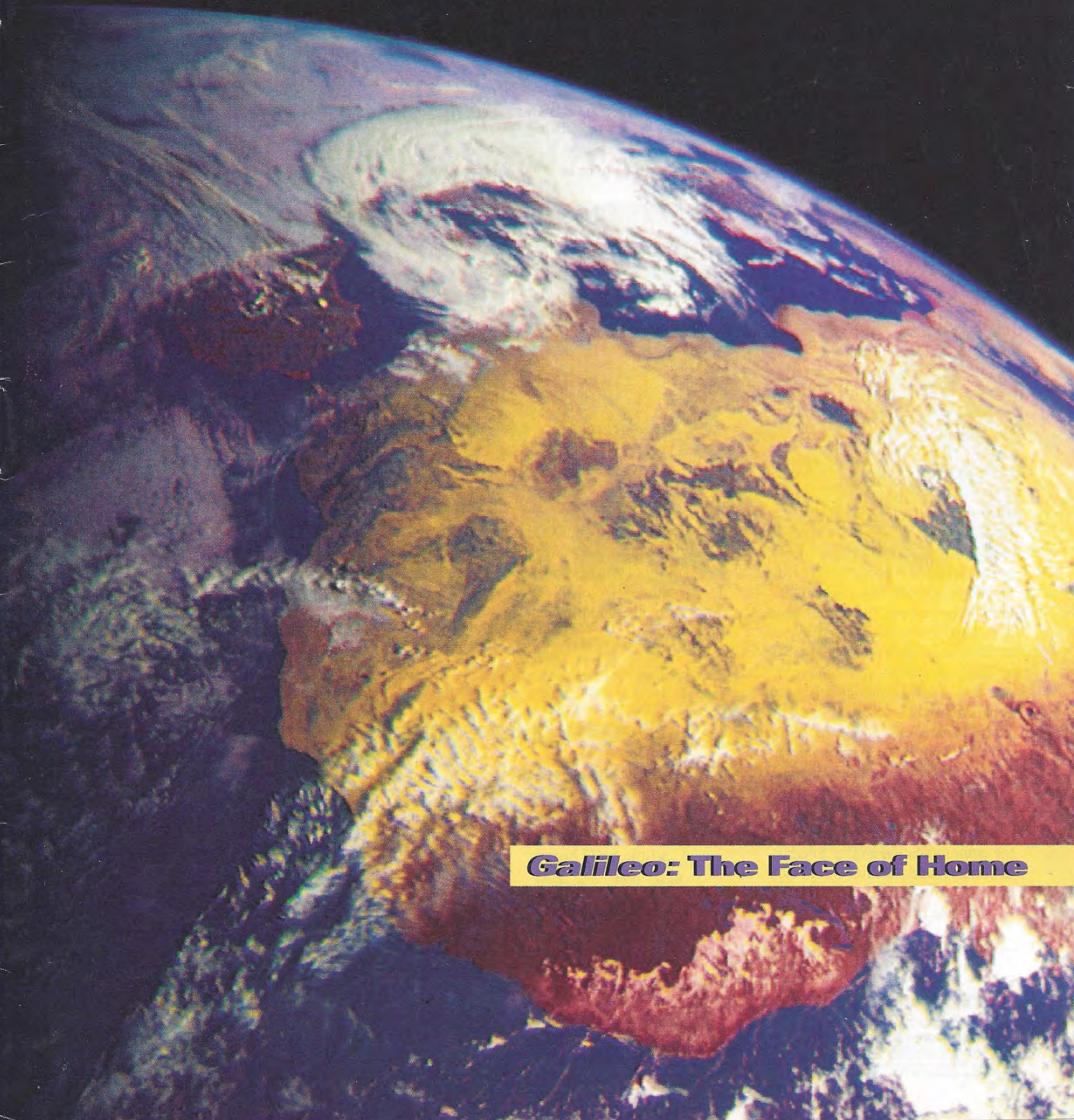
The PLANETARY REPORT

Volume XV Number 3 May/June 1995



On the Cover:

Seen through eyes other than our own, the planet Earth appears as a strange but beautiful place. The *Galileo* spacecraft on its way to Jupiter took this image of West Africa and the Mediterranean Sea from about 600,000 kilometers (400,000 miles) away. The spacecraft's camera was looking through infrared filters sensitive to light wavelengths unfamiliar to the human eye. Images taken this way provide information about things such as the location and health of vegetation and the water content of clouds. *Galileo*'s portraits of the planet could be valuable reference points for future Earth-monitoring spacecraft.

(See page 10 for a complete caption.)

Image: Paul Geissler, Lunar and Planetary Laboratory, University of Arizona

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From The Editor

Communication is the reason The Planetary Society exists—to bring the results of planetary exploration to the public and to convince the nations of the world that it is an endeavor worth pursuing. Our activities center on communication: influencing governments, publishing the magazine and newsletters, and bringing together people who share our goals.

We support another sort of communication: dialogue among our members and with the Society's directors and advisors.

If you don't regularly read our Members' Dialogue column, take a look at this installment. I think you'll find the letters particularly thoughtful and thought-provoking. Everyone can take advantage of Members' Dialogue to communicate with others in our Society.

There are other means of communication you can use: e-mail (TPS@genie.geis.com) and our home page on the World Wide Web (http://wea.mankato.mn.us/TPS/). We also have a new roundtable on GEnie where members can meet electronically. If you have a modem, dial up 800-638-9636 to join GEnie and our roundtable. Let's increase the communication among Society members—and together we'll find new ways to advance our goals.

—*Charlene M. Anderson*

Features

Departments

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Members' Dialogue

Exploration Debate?

Is the drive to explore genetic, something hardwired into humans, or is it merely social software, something that comes and goes from culture to culture and from time to time? This question has particular significance with regard to space exploration.

Carl Sagan and others on the genetic side of the debate tell us that the human expansion into space is inevitable, a part of the natural evolution of the universe. Arizona State University historian Stephen Pyne points out that this approach can lead to complacency, absolving us from the necessity of making real-world, real-time decisions to actually make it happen. Like most cultures throughout history, our society may restrict or even eliminate geographic exploration from its values set. The 15th-century Confucians did exactly that, effectively erasing the knowledge of an outside world from the collective consciousness of the Chinese people.

Equally disturbing is the lack of urgency on the part of Sagan and others who promote the "exploration is in our genes" theory. Canadian anthropologist Charles Laughlin maintains that there is only a limited time during which we can effectively get the space expansion under way. As earthly problems mount, we may soon lack the strength and resources to move into this new frontier. If we're really serious about space exploration, then we must make it happen soon.

Pyne maintains that the urge to explore is not genetic at all but instead is part of the cultural heritage of the West. Regardless, the "self-evident" genetic approach has made us lazy and ineffective in the pro-space arguments. Let's debate this issue properly before space exploration is relegated to the history books!
—TOM HARRIS,
Kanata, Ontario, Canada

To the Moon

We were glad to learn that the Europeans are looking at the Moon very closely (see "Taking the Next Step," by R.M. Bonnet in the January/February 1995 issue of *The Planetary Report*). Exploration of the Moon in a sensible way should provide an excellent international space program, and the European Space Agency can surely play a central role in it.

The reasons for the Moon program mentioned in the article are good ones. However, we wonder if the Bonnet committee ever considered possible adverse effects of our presence on the Moon. The stated "problems inherent to a lunar base" merely represent technical problems that would inconvenience work on the Moon. Can our presence on the Moon cause a gradual, yet significant problem for its environment in the future? Just as our presence has on Earth? We believe that one of the roles of The Planetary Society is to examine more closely questions such as these.

Finally, it would have been nice if Bonnet had given cost estimates of the MORO and LEDA projects. This could have helped us get some feeling for the size and extent of the projects discussed.
—TAKAO TANIKAWA and
NAN Y. HIRAIWA, *Tokyo, Japan*

The article on the European Moon program was timely and very interesting. It also points out a potential direction for the Society in future efforts: Rather than pushing for exploration of Mars (which now looks like a long shot considering the costs and political realities), let's begin supporting an international effort to return to the Moon for long-term activities.

The Moon is not as exotic as Mars, but it is closer and therefore much cheaper to access. The Moon offers commercial and scientific potential that Mars does not, and it is probably humankind's best near-term bet for continued productive activities beyond low Earth orbit. If the important criteria for the Society's support of a proposed program are international cooperation and nurturing our spacefaring capabilities for the betterment of humanity, then a global effort to begin exploitation of lunar resources for commercial and scientific projects should be a major Planetary Society focus.

Let this be a call for a debate within the Society—"Moon or Mars? The Near-Term Future of Space Exploration."
—PAUL KLARER,
Albuquerque, New Mexico

SETI Pioneers

I very much enjoyed the article on SETI before the space age by Steven J. Dick in your January/February 1995 issue. An equally delightful and informative article, "Calling All Martians," by Willy Ley was published in the November 1940 issue of *Thrilling Wonder Stories*.

In this piece Ley recalls the efforts by scientists to communicate with what many assumed would be intelligent life on Mars. A proposal by German mathematician Karl Gauss suggested that the Siberian tundra be used as a way to signal other beings. Ley said, "Viewed from an elevation, forests show dark against the frozen background of the tundra. We had but to plant forests in those tundras, forests so laid out that they formed geometrical patterns. . . . Such an artificial symbol would prove to the Martians that their planetary neighbors were intelligent. At the very least it would prove that we knew geometry."

Ley reviews what information should be in a "letter of introduction" to the Martians when people go to Mars, and while he will not make a guess as to when they will go, he certainly believes that it will happen.
—MARSHA FREEMAN,
Washington, DC

Please send your letters to Members' Dialogue, The Planetary Society, 65 North Catalina Ave., Pasadena, CA 91106-2301.

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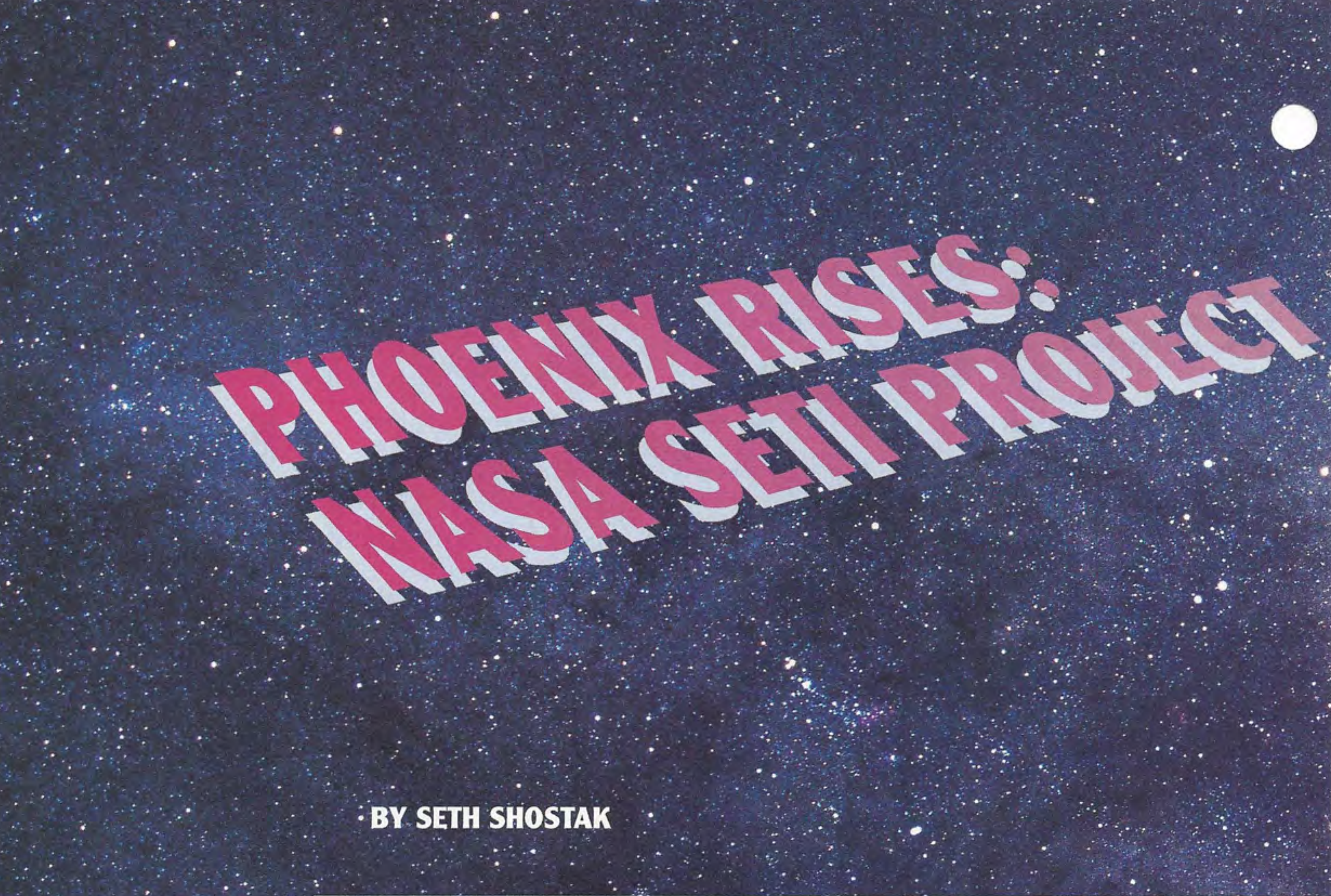


PHOENIX RISES: NASA SETI PROJECT

BY SETH SHOSTAK

While often praised for its aesthetics, there's no denying that the Parkes radio telescope resembles a prop from a cheesy sci-fi movie. Its 64-meter-diameter (210-foot) reflector, looking like a satellite dish on steroids, squats menacingly atop a pinkish-gray cylindrical tower. Rows of white-framed windows punctuate the structure, and the total effect is that of an isolated, hi-tech lighthouse in a vast sea of Australian bush.

But Parkes is a lighthouse in reverse. It doesn't signal; it listens. Currently, its oversized metal ear is being pointed in the directions of nearby stars in hopes of hearing the faint tone that would betray an extraterrestrial civilization.

Parkes is hosting the first observations for Project Phoenix, the SETI Institute's program to systematically scrutinize the vicinities of about 1,000 Sun-like star systems for signs of intelligence. Phoenix traces its lineage to the NASA SETI (Search for Extraterrestrial Intelligence) program that was axed by a budget-conscious Congress in the fall of 1993. That ambitious undertaking had two principal components: a targeted search to make sensitive observations of nearby star systems, and an all-sky survey to sweep the entire sky, albeit at lower sensitivity.

The observations for the NASA program had just begun when it was throttled by congressional action. Fortunately, the SETI Institute, a nonprofit research organization in Mountain View, California, was able to find private monies to continue the targeted search part of the NASA effort. Engineers and scientists at the institute have spent a year upgrading the receiving equipment (on long-term loan from NASA) in preparation for observations expected to last until the year 2000.

Where Phoenix Is Looking

The stellar targets to be observed by Phoenix are as carefully selected as Marine recruits. David Soderblom, of the Space Telescope Science Institute, and David Latham, at the Harvard Center for Astrophysics, have compiled a list of the nearest of Sol's cousins (the majority are G-type stars, so their mass and brightness are similar to those of the Sun). Young family members, stars less than 3 billion years old, have been tossed from the list. So have those with close-by stellar siblings. Only stars believed capable of hosting planets, and long-lived enough to have brewed some biology on those planets, have made Phoenix's final cut.

Among the project's select list of candidates are approximately 200 stars more than 35 degrees south of the celestial equator. These deep-south objects are invisible to major radio telescopes

Background: A thick stream of stars distinguishes the Milky Way as seen from Earth's southern hemisphere. Since more stars—hence more potential solar systems—are visible from those latitudes, southern telescope sites are particularly valued for SETI observations. Photograph: Dennis diCicco

north of Earth's equator, and that explains why collaboration with the Australians is so vital. Southern observations are required, but not just any telescope will do because Project Phoenix is predicated on a very sensitive search of its chosen targets. "We're sensitivity chauvinists," says Jill Tarter, the project scientist. The Phoenix approach mandates using the biggest antennas possible, and the Parkes telescope is unsurpassed among the large astronomical dishes of the southern hemisphere.

Of course, collecting area isn't everything. It's equally important to make a minute inspection of the radio dial to optimize the chances that you're tuned in where the extraterrestrials have turned on. Ever since the pioneering SETI work of Philip Morrison and Giuseppe Cocconi, astronomers looking for cosmic company have narrowed their search to the microwave region of the radio dial. Not only is the natural static from the galaxy at a minimum here, but the band also boasts a conspicuous signpost in the guise of the 1,420-megahertz line of neutral hydrogen. This line is a universal marker, surely known to all the advanced beings in the galaxy. SETI researchers have proposed dozens of other "magic frequencies" where they believe extraterrestrials would tune transmitters intended to attract the notice of faraway societies. But the 1,420-megahertz line continues to be the hands-down favorite, the sweet spot on the dial.

Despite this, Project Phoenix will press its systematic hunt for signals in a significantly wider chunk of the microwave band. "This is not just a magic frequency search," notes Tarter. "We're not limiting ourselves to human imagination."

As the massive Parkes telescope slowly tracks its stellar prey, the Phoenix receivers are stepped from 1,200 to 3,000 megahertz, in 20-megahertz increments. Each spectral increment is divided into as many as 28 million channels, providing frequency resolution down to a hair-fine 1 hertz. That's 5 million times smaller than the bandwidth of a television broadcast, but the SETI researchers are looking for the narrow carrier wave that underpins radio transmissions. Such a carrier is invariably of small spectral width, and it is this property that immediately distinguishes an artificial signal from the broadband static caused by the universe's natural radio generators.

How It Works

The spectral analysis is thoroughly automated. Approximately once each second, high-speed digital processors do a signal inventory. All 28 million channels are examined to see if any have

Gazing across our home galaxy, one might wonder how many stars might possess planets that support life.

Painting: Jon Lomberg

A poster of this painting is available for purchase; *see page 22.*

accumulated a significant amount of radio energy, much as you might scan a row of mailboxes for mail. If some are found, their number and contents are written down. Then the process continues for another second.

A steady signal would fill the same channel, or mailbox, repeatedly, making itself obvious to both the digital processors and the astronomers. However, it's more likely that a real hailing alien will be on a rotating planet. The relative velocity of extraterrestrial transmitter and Earth-based receiver will be changing, and this introduces a varying Doppler shift in the received signal, even after taking out the known shift due to Earth's rotation. The extraterrestrial "mail" will slowly hop from mailbox to mailbox.

Project Phoenix's high-speed hardware is unique in being able to spot such peripatetic mail, signals that drift as fast as 1 hertz per second. It can also recognize transmissions that are pulsed, such as a rotating beacon might produce. "This would be the most energy-efficient way for the aliens to send us a signal," according to Jay Duluk, one of the principal architects of the Phoenix receivers. "Pulsed transmissions are like the flashing xenon lamps on airplanes. You can put a lot of power into the flashes and make them brighter than anything around, even though the average power required is low." Pulses with repetition rates of up to two minutes can be recognized in the torrent of data pouring into the Parkes telescope.

Project Phoenix will spend four months observing in Australia and will then bring its sophisticated receivers back north to continue the search. It is one of four major SETI programs currently under way at radio wavelengths. The Planetary Society's META (Megachannel Extraterrestrial Assay) project is busy scanning the entire sky at frequencies close to the 1,420-megahertz hydrogen line in both the northern and southern hemispheres. SERENDIP, a SETI experiment run by a team at the University of California, Berkeley, gets data at frequencies near 430 megahertz day in and day out by "piggybacking" on astronomical programs that run on the 305-meter-diameter (1,000-foot) Arecibo radio telescope in Puerto Rico. A third sky scan is being conducted by a group at the Ohio State University observatory, also homing in on frequencies near 1,420 megahertz.

Tracking the Terminology

Optical astronomers usually describe light's color by its wavelength. For example, yellow light has a wavelength of about 5,600 angstroms, an angstrom being one 10-billionth of a meter. The wavelength is the distance between successive wavecrests of the oscillations that make up the light. It is convenient to use these (admittedly small) units, because mirrors and lenses have to be produced to tolerances that are prescribed by the wavelength of the light they are designed to reflect or bend.

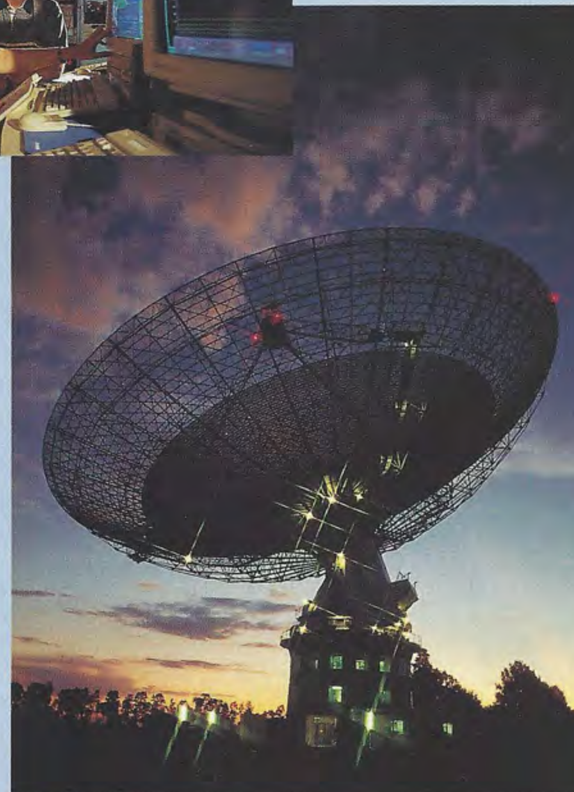
Radio astronomers, on the other hand, have historically been engineers first and scientists second. They often describe radio waves (which, after all, are simply another form of light) in terms of frequency, rather than wavelength. A 300-meter-wavelength radio signal has a frequency of 1 million cycles, or oscillations, per second. The hertz, named after radio pioneer Heinrich Hertz, is a convenient, one-word syn-

These search programs frequently find "alerts," interesting signals that might possibly be of extraterrestrial origin. Of course, no one will either claim or believe that the aliens are on the air until the extraterrestrial nature of such a signal can be confirmed. Tracking down these tantalizing alerts, frequently caused by television broadcasts, military radar or communications satellites, is a time-consuming task for any SETI project. Even the simplest confirmation exercise—moving the telescope off target and seeing if the signal goes away—can eat up lots of valuable search time because interference is plentiful and becoming more so.

Project Phoenix has built a special subsystem to help sort the false alarms from the fires. A so-called "follow-up detection device," or FUDD, is used to check out suspicious signals with a second telescope, the 22-meter-diameter (72-foot) Mopra antenna located in the kangaroo-riddled outpost of Coonabarabran, about 200 kilometers (120 miles) north of Parkes. During the course of observations, a bit of FUDD electronics at Parkes zeroes in on any signals its 28-million-channel big brother has identified as likely candidates.

After accurately characterizing these interesting emissions in terms of their exact frequency, bandwidth and frequency drift, it sends the parameters to the Mopra FUDD. The Coonabarabran dish then determines whether any candidate has the characteristics appropriate to a true extraterrestrial transmission.

The automatic FUDD filtering eliminates the majority of terrestrial interference, greatly improving the efficiency of the search and permitting astronomers to reobserve only those signals worthy of the effort. The bottom line is that Project Phoenix will be capable of near real-time confirmation. Should Parkes pick up the faint tone of a distant society, it will be quickly recognized.



Above: Peter Boyce, Jill Tarter and Peter Backus (left to right) monitor the Phoenix equipment from the control room at the Parkes radio telescope.

Right: Set against a twilit sky, the dish of the Parkes radio telescope searches the vicinity of carefully selected stars for possible signals from other civilizations. Project Phoenix is the reborn targeted search portion of the canceled NASA SETI program.

Photographs: Seth Shostak

Why We Keep Searching

But will that happen? After 30 years of luckless SETI searches, is there any reason to think that Project Phoenix will finally satisfy our curiosity about the existence of other sentient beings? No one can say, of course. The answer depends on factors whose values are still either unknown or speculative. How many stars have encircling planets? How often does life emerge on terrestrial planets? How persistent are technological societies?

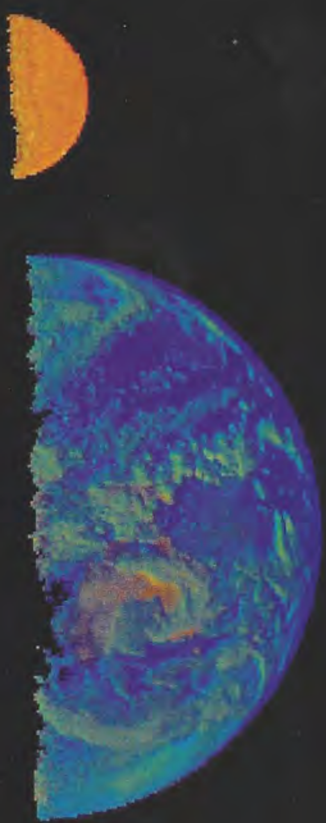
There is no reliable bookmaker to set the odds. But the 20 scientists and engineers toiling in the Australian bush feel that one fact is certain: We cannot hope to find our place in the cosmos unless we look for it. We must do the experiment. Project Phoenix, with its systematic search of the nearest stars, its very wide frequency coverage, its ability to recognize drifting and pulsing signals, and its unprecedented sensitivity, is surely one of the most intensive such experiments ever begun.

The night air in Australia is warm, and the dish of the Parkes antenna groans softly as it tracks a dim star set in the fabulous spangle of the southern sky. Enveloped by the gentle dark, the telescope appears not as an ungainly construction in a faraway landscape, but as a door opening onto the unfathomed corridors of the universe.

Seth Shostak is a radio astronomer and filmmaker who works at the SETI Institute.

onym for "cycle per second" and is itself abbreviated as Hz. Kilohertz (KHz), megahertz (MHz) and gigahertz (GHz) refer to a thousand, a million and a billion hertz, respectively.

While AM radio frequencies are measured in kilohertz, and television frequencies are tallied in megahertz, the frequencies used for SETI are usually in the gigahertz region. Because of their short wavelengths, only centimeters long, radio signals between about 1 and 30 gigahertz are referred to as microwaves. They are particularly effective at heating the water molecules in substances such as turkey and meat loaf, which explains their use in microwave ovens. But it is a fact that the galaxy is quietest in the microwave part of the radio dial. Naturally generated radio static is at a minimum here. This circumstance was recognized more than 30 years ago and is the reason most SETI experiments are tuned to the microwave spectral region. After all, if you want to hear a whisper across the depths of space, it helps to have a bit of quiet. —*SS*



Encounter With Earth: *Galileo* Explores Its Home Planet

by Paul E. Geissler

ABOVE: 6,100,000 kilometers (3,800,000 miles)—16 times the Earth–Moon distance, eight days' travel time from closest approach to Earth. A color-ratio image (left) is compared with a false-color composite (right) produced from the violet, 0.73- and 1-micron filters. Earth and the Moon are lined up in conjunction, with the Moon above and in front. Australia is visible near the terminator of the illuminated side of Earth. To the east can be seen the bright glint of sunlight on the ocean. This is one of 56 frames from an 18-hour time-lapse sequence that has been made into a remarkable color animation. It records Earth spinning on its axis as the Moon appears to cross from left to right from the perspective of the rapidly departing spacecraft.

All images, except where noted: Paul Geissler

The space probe has traveled 2 billion kilometers and twice circled the central star of this average-looking solar system. As if awakening from a sleep, the sensors and instruments come alive as it approaches the 3rd planet. The glint of sunlight reflected from the blue surface and the distinctive spectral signature of chlorophyll hint that something is different about this world…

Still half a year away from its final destination and primary mission at Jupiter, the *Galileo* spacecraft has already sent back thousands of images of Earth, the Moon, Venus and the asteroids Gaspra and Ida. Launched by the space shuttle *Atlantis* on October 18, 1989, *Galileo* was placed on a gravity-assist trajectory that included two close encounters with Earth in order to boost the velocity of the spacecraft to reach Jupiter in December of 1995.

The first of these encounters occurred on December 8, 1990, when the spacecraft passed over the Caribbean Sea at a distance of 960 kilometers (about 600 miles). Exactly two years later, the probe passed only 302 kilometers (about 190 miles) above the South Atlantic and began recording images and other scientific observations on the outward leg of the journey to Jupiter. The malfunction of *Galileo*'s high-gain antenna did not hinder the Earth and Moon observations because the close flybys made it easy to record the weaker signal from a low-gain antenna.

Although Earth is surrounded by an impressive array of orbiting spacecraft that continually collect remote-sensing data, the *Galileo* images offer a unique perspective on our home planet in two respects. The first is a view of Earth from a range of distances, from the remoteness of deep space to suborbital close-ups showing apparent signs of human habitation. The observations made during the two Earth flybys were similar to those obtained by robotic explorers of the other planets in our solar system; these data show Earth as it might appear to an alien probe passing through on a mission of discovery. They also offer planetary scientists an opportunity to develop and test techniques to be used in the exploration of Jupiter and its moons.

The second unique aspect is the spectral capability made possible by four narrowband filters—

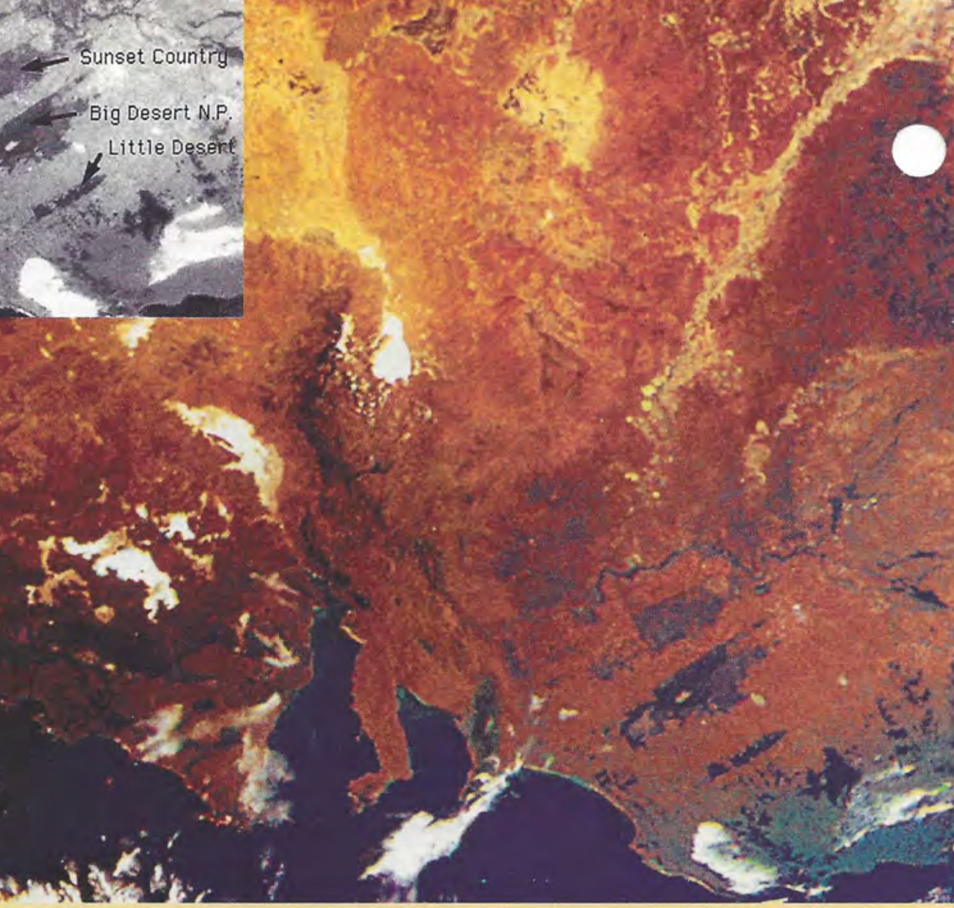
intended for observations of methane in Jupiter's atmosphere—that measure the brightness of reflected light at specific infrared wavelengths. The *Galileo* pictures differ from standard satellite false-color images from the Landsat Multi-Spectral Scanners, the Thematic Mapper and the Advanced Very High Resolution Radiometer in unexpected ways. For example, two of the filters coincide with an infrared signature of vegetation that is diagnostic of the species type and state of health of plant life. Another filter corresponds to the center of a narrow absorption band of ferric oxide minerals. Condensed water and water vapor in clouds can be uniquely discriminated by *Galileo* using weak absorptions in their near-infrared spectra.

The *Galileo* data offer a preview of some of the surprises in store for the future, when remote-sensing systems such as EOS (the Earth Observing System) will make global surveys at much higher spectral resolution than is presently possible. Few humans will be lucky enough to view Earth from the window of a spacecraft—the rest of us must be content with postcards sent home by robotic explorers like *Galileo*. The selection of pictures that follows presents a portrait of what is undoubtedly the most interesting and beautiful planet in this solar system.

Paul Geissler is a Galileo *imaging team associate and a planetary scientist at the Lunar and Planetary Laboratory of the University of Arizona. His research interests include remote sensing of planetary surfaces and the dynamical environments of small asteroids.* *Special thanks are due to Reid Thompson, Richard Greenberg, Carl Sagan, Michael Belton and the* Galileo *imaging team for contributions to this article.*

Note: Computer-readable copies of the raw *Galileo* image data can be obtained on CD from the National Space Science Data Center in Greenbelt, Maryland. These data have already found applications to teaching science in secondary school classrooms. The *Galileo* project, whose primary mission is the exploration of Jupiter in 1996–1997, is managed for NASA by the Jet Propulsion Laboratory.

BELOW: 1,050,000 kilometers (650,000 miles)—2.8 times the Earth–Moon distance, 31 hours from closest approach.* Galileo *captured this view of the partially illuminated Australasian hemisphere using the 1-micron, green and violet filters. Vegetation appears red in this false-color composite, so that even small islands like Tasmania can be seen to the south of Australia, as can cloud-covered New Guinea and the Solomon Islands to the north. At visible wavelengths, these regions appear dark and inconspicuous because of the efficient absorption of visible light by chlorophyll for photosynthesis. The brightening of the ocean off the coast of Queensland is due to specular (mirror-like) reflection of sunlight from the sea surface.



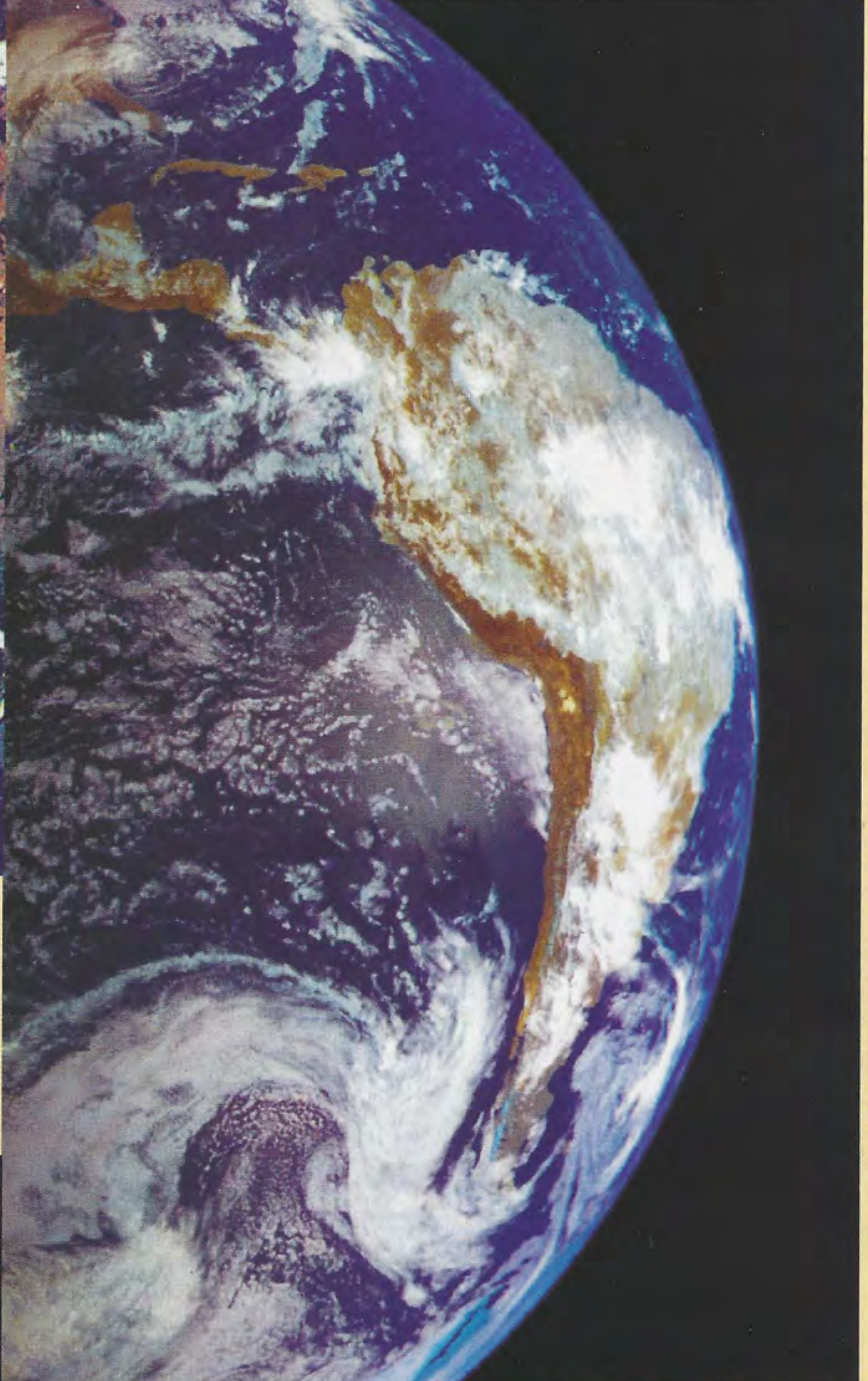
FAR RIGHT: *187,000 kilometers (116,000 miles)—roughly half the Earth–Moon distance, six hours from closest approach. Racing by at a speed of over 30,000 kilometers (19,000 miles) per hour,* Galileo *recorded this visible-light image of eastern Australia, showing parts of the states of South Australia, New South Wales and Victoria. The yellow regions (top) are vast sand sheets in the interior of Australia, the Simpson and Sturt deserts. The bright white areas below these sands are not clouds but dry lake beds or playas—optimistically called "lakes" by the Australians: Eyre, Frome, Torrens and Gairdner. Vegetated areas near the right side of the picture appear dark green (forests) or light green (grazing and cropland, as seen along the coast of Victoria). Above these, a block of dark-red rocks can be seen to the east of the Darling lineament, a major structural fault.*

INSET: Signs of life. Geometric outlines can be seen near the center of this picture: The straight line running due south from the prominent crook in the Murray River is the border between Victoria and South Australia. It is visible because of differences in land use; agricultural areas lie to the west of this border, while the land is sparsely inhabited on the Victoria side. More suspicious are the linear east–west trending margins of two wilderness areas in the south. To an extraterrestrial passing through the solar system, such modification of the landscape might be taken for evidence of intelligent habitation of this planet.

ON THE COVER: West Africa and the Mediterranean Sea. The Sahara Desert appears yellow in this infrared composite taken about 600,000 kilometers (400,000 miles) from Earth. Black areas in the Sahara are rocky mountain ranges. Vegetation (red regions) flourishes in Spain and along the Ivory Coast of Africa. Lake Chad can be seen as a dark red-brown semicircular spot near the right-hand side of the picture. Vegetation near Lake Chad is rapidly vanishing with the desertification currently taking place in the Sahel (the transition zone between the Sahara and the vegetated equatorial part of Africa). Regional images such as this may be extremely valuable as a reference point for monitoring processes of global change when similar data from orbital spacecraft like EOS become available in the future.

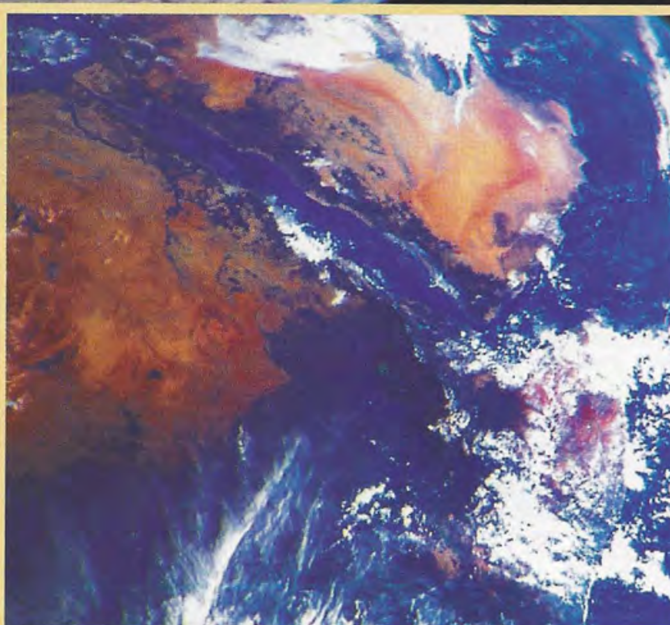
Clouds of two colors can be distinguished over Europe and in the Atlantic off the coast of Africa. High-altitude clouds are composed mainly of ice crystals, with little water vapor, and appear white in the Galileo *image. Low, moist clouds have a magenta or purple tinge caused by a weak water-vapor absorption at infrared wavelengths, an absorption too narrow to be measured by any currently operating orbital spacecraft. An interesting time-lapse sequence produced by Reid Thompson of Cornell University shows the development of actively precipitating thunderstorms in the Amazon basin using this unique spectral capability of the* Galileo *imaging system.*

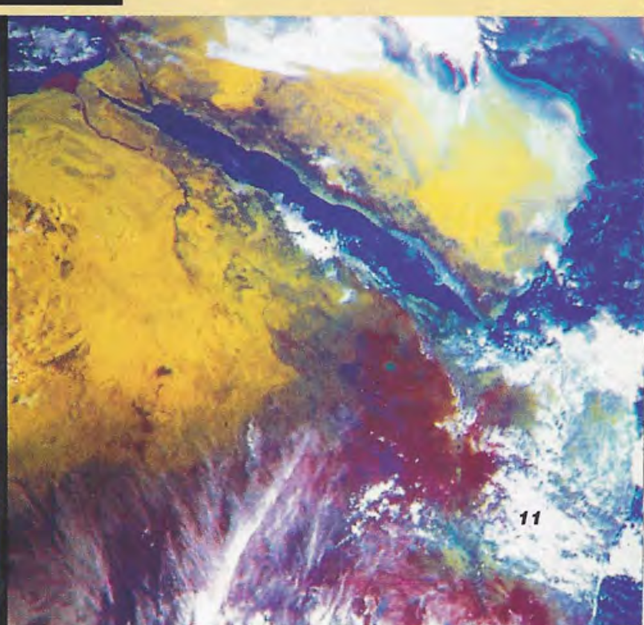
BELOW: India and Tibet at Earth's limb. This is a false-color composite produced from the 1-micron, red and violet filter images at a range of 264,000 kilometers (164,000 miles). The Tibetan plateau appears orange, and the blue bank along its southern margin is the Himalayan range. Dark spots behind the Himalayas are Tibetan lakes. The Ganges and Brahmaputra rivers are barely visible to the south. The smooth-looking region northwest of Tibet is the Tarim basin, site of the Takla Makan Desert and the old Silk Route to China. Snow in the Hindu Kush mountains (blue-white region southwest of the Tarim basin) is spectrally distinct from the reddish clouds over Iran due to a water-ice absorption band near 1 micron. To the south are the folded and convoluted mountains of Pakistan, the result of the collision of the Indian subcontinent with Asia. A narrow strip of cultivated land along the Indus River valley lies between these ranges and the Thar Desert to the east. Three partially filled lake beds are seen near the coast just east of the Indus in a former inlet in western India known as the Great Rann of Kutch.



LEFT: South America slipping over the horizon, from 750,000 kilometers (470,000 miles). The eastern seaboard of the United States can be seen at the top of the picture. The cloud-filled Amazon basin appears green in this false-color infrared image. The brown area on the crook of the west coast of South America is a high desert known as the Altiplano. The white spot in the middle of the Altiplano is Salar de Uyuni, the largest dry lake bed in the world, with an area of 9,000 square kilometers (3,600 square miles). Thin blue lines mark snowfields in the Andes and the mountains of Patagonia. Image: USGS Flagstaff

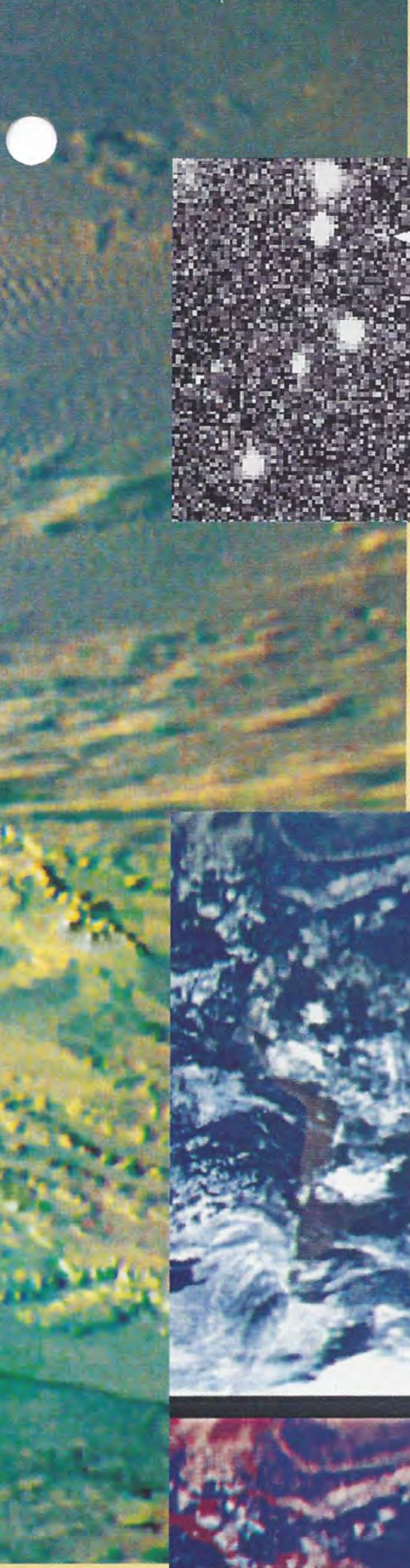
BELOW: Comparison of visible (left) and infrared (right) images of Arabia and North Africa from 493,000 kilometers (306,000 miles). Somalia was under cloud on December 8, 1992—poor weather for the landing of US Marines that was taking place on the same day. Deep-red coloration is visible at the margins of the Rub' al-Khali or Empty Quarter of Arabia, site of the largest "erg" or sand sea on Earth. The coloration is probably due to coatings or "varnish" present on the grains of older, more stable dunes and absent from actively saltating (moving) sands. Vegetated regions in the Nile delta and the Ethiopian highlands appear with red to purple hues in the false-color picture on the right. Intense volcanism associated with tectonic activity produced the highlands of Ethiopia, which because of their 2,500-meter (8,000-foot) average height are vegetated despite being surrounded by desert in the Sahara, Arabia and Somalia. Three major rifts are found in this region: Spreading centers along the Red Sea, the Gulf of Aden and the African Rift Valleys converge on the Afar Triangle at the center of the rifts, an area of geologically recent basaltic volcanism that is indistinct at visible wavelengths but markedly different in color from the ancient continental crust in the false-color composite. Arabia neatly fits the outline of the coast of North Africa with the younger volcanics of the Afar region removed, as it did prior to this recent expression of plate tectonics.

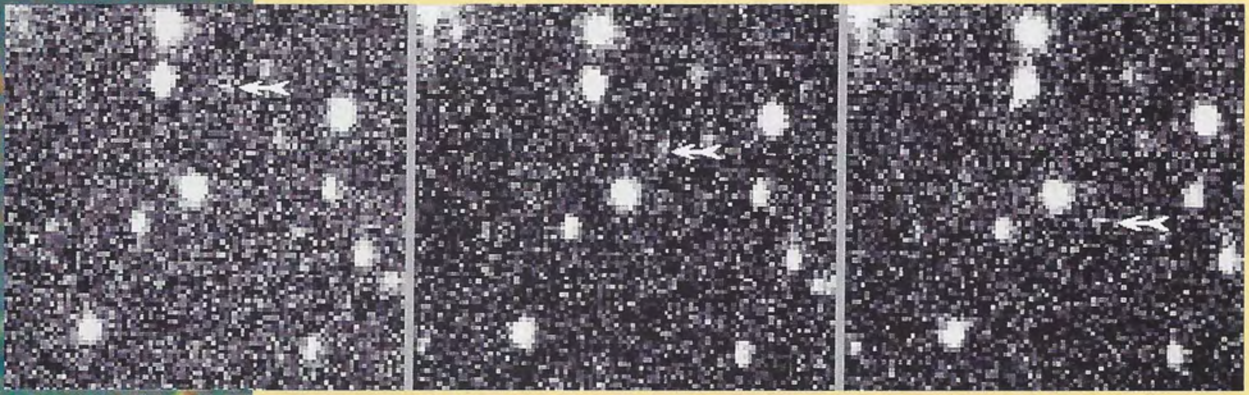




ABOVE: Ross Ice Shelf, Antarctica, range 75,000 kilometers (47,000 miles). A jet of high-altitude cloud crosses McMurdo Sound from the Ross Sea to the Wilkes Land interior in this high-resolution image oriented with south toward the top. Behind the jet, a lee wave structure has developed in low-lying clouds through the interaction of the flow of the atmosphere with surface topography at the Transantarctic Mountains. The Dry Valleys can be seen beside these clouds as black, snow-free zones near the coast. Almost everything visible in this scene is made up of water. The colors in the picture are due to differences in the physical form of the water: coarse-grained sea ice (deep cyan or blue-green); continental snow (pale cyan); moist, precipitating clouds (magenta); dry clouds composed of micron-sized ice crystals (white); and liquid oceans (dark blue-black).

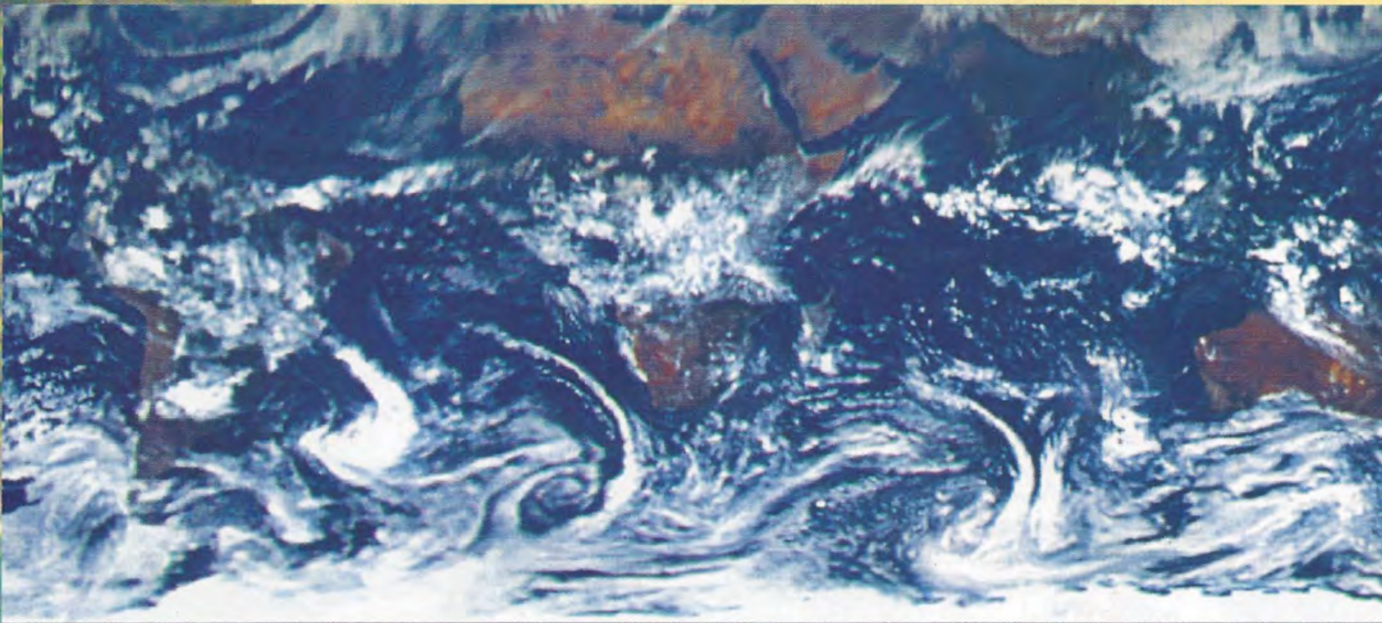
RIGHT: Multispectral mosaic of latitudes 30 degrees north to 70 degrees south. This compilation of images from the first Galileo *encounter shows a "snapshot" of our planet on a single day (December 11, 1990). To the unaided eye (top), only the deserts of Earth appear prominent beneath the clouds: the Altiplano, Arabia and the Sahara, the Namibian Desert of southern Africa, and central Australia. Vegetation differences, especially between India and Southeast Asia, are noticeable at infrared wavelengths (bottom). Tropical convection clouds encircle the planet at the equator, while a ring of spiral circumpolar cyclones dominates the southern oceans.*

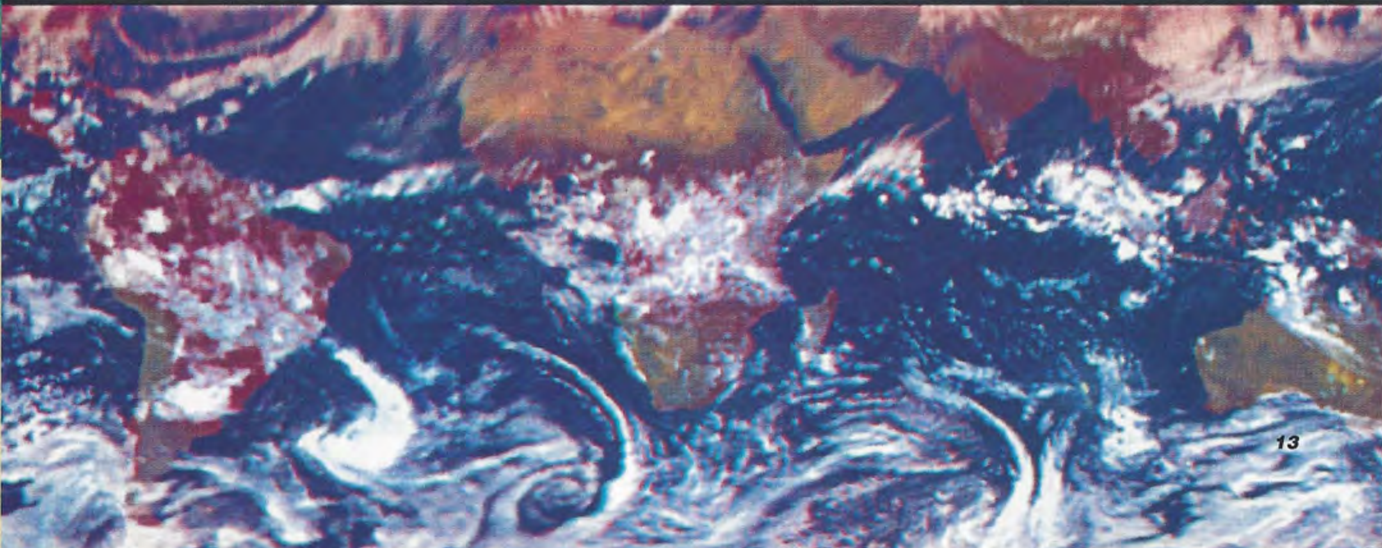




ABOVE: Portrait of the photographer. As Galileo *approached and prepared to take pictures of Earth, astronomer Jim Scotti imaged the spacecraft on November 28, 1992, using the Spacewatch telescope at the University of Arizona. At a distance of 8,100,000 kilometers (5,000,000 miles) this is the farthest optical detection of a human-made object in space to date. The three frames show the motion of the probe against a background of stars at half-hour intervals. (Arrows are added to show the location of* Galileo*, a mere point of light at this distance with a visual magnitude of about 22.)*

Image: James Scotti, Lunar and Planetary Laboratory, University of Arizona





Basics of Spaceflight: Gravity Assist

by Dave Doody

In the March/April issue of *The Planetary Report,* we considered a method for flying to a nearby planet: To reach Mars, you'd typically burn propellant to create a solar orbit having Earth as its closest point to the Sun (perihelion) and Mars as the far point (aphelion) in the ellipse—a Hohmann transfer orbit.

In this issue, we'll talk about gravity assist, which makes it possible for a spacecraft to reach the distant outer planets without using vast amounts of propellant. Michael Minovitch, a student working at the Jet Propulsion Laboratory for a few summers in the 1960s, helped develop this marvelous technique. Astronomers had long known that comets' orbits were altered by encounters with planets, but it was Minovitch who first recognized that the principle could be applied to spacecraft trajectories.

Mariner 10, both *Voyagers* and *Pioneer 11* all used the technique, as did *Galileo,* which encountered both Venus and Earth for gravity assist, gathering speed to get to Jupiter. *Cassini,* launching in 1997, will also use these planets, with an additional assist from Jupiter to accelerate for the flight to Saturn.

What Good Is Gravity?

When I first heard of gravity assist, I wondered how gravity could be of any use to a spacecraft when it flew by a planet on its interplanetary trajectory. Sure, you'd speed up on the way in to the planet, in fact quite a lot on the way in to a massive planet like Jupiter. But then it seemed that you'd just slow down again once you passed the planet, gaining nothing in total.

Consider someone bicycling down a road into, and then up out of, a valley. The cyclist will speed up approaching the valley floor, having gained momentum. But just as surely, all that momentum will be lost on the way back uphill, and the cyclist will slow down. Speed will also decrease as a result of friction with the atmosphere and the road. Of course, in interplanetary space, there isn't any friction, so your outbound speed will zero out exactly.

Well, then, what good is gravity for interplanetary travel, anyway? Roll a marble down the inside of a bowl to demonstrate the same thing: The speed you attain going toward a planet (Earth, if that's where you are with your bowl and marble) just gets drained away as you climb up away from the planet—*relative to the planet*. That's the key! If the bowl (planet) is moving relative to the marble and everything, it'll be a different story.

Voyager started out with a Hohmann transfer to Jupiter. If Jupiter hadn't been there, the spacecraft would have fallen back around the Sun in a big elliptical orbit forever. But let's think about the whole picture: *Voyager*, coasting in its solar orbit, gets close enough to the gas giant for Jupiter's gravity to cause the spacecraft to speed up. Then, as *Voyager* passes close by Jupiter, it starts to slow down. If you were sitting on Jupiter, you'd see *Voyager*'s speed just decrease back to its original incoming speed. (Figure 1 illustrates this using vectors, a simple shorthand in which an arrow's direction indicates an object's direction of travel and its length indicates the object's speed.) But from the Sun's point of view, something totally different happens! In a minute, we'll see just what that is.

Consider Jupiter orbiting the Sun, going around in the same direction as the other planets. It has a huge amount of momentum as it

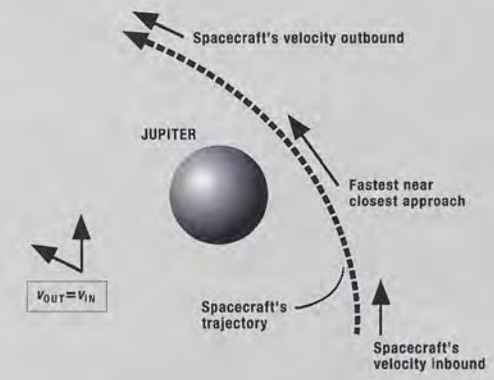


Figure 1. Relative to Jupiter, the spacecraft ends up with the same velocity, v, leaving as it had coming in, even though it accelerates during flyby.

Drawings by Dave Doody, rendered by B.S. Smith

For further reading: "Gravity's Overdrive" *Air & Space/ Smithsonian*, February/March 1994; JPL's *Basics of Space Flight* on the World Wide Web at Universal Resource Locator http://oel-www.jpl.nasa.gov/basics/bsf.htm.

circles the Sun. Since we're talking about going around in a circle, constantly changing angle in relation to the Sun, it's called angular momentum.

To begin to imagine Jupiter's angular momentum, "orbit" a marble around you by swinging it on a string a foot long. You can catch the marble and stop it easily enough. Let's call this marble Earth, orbiting the Sun.

Now think what it would be like to swing a bowling ball (Jupiter) around you on a rope several yards long. You surely wouldn't want anyone to try to catch it. It would have too much angular momentum. These examples are not really in scale with Earth and Jupiter, but you get the idea: A massive planet orbiting a large distance from the Sun is a repository of angular momentum.

Transferring Momentum

A baseball bat has a good deal of angular momentum while the batter is swinging it. If it connects with a slow-moving softball, some of that energy is going to transfer from the bat to the ball, accelerating the ball away from the batter and making the bat slow down.

That's what happened with *Voyager* and Jupiter. *Voyager* connected with Jupiter through gravitational force (rather than through direct mechanical force, as with the softball, thank goodness), and in doing so it soaked up some of Jupiter's vast angular momentum.

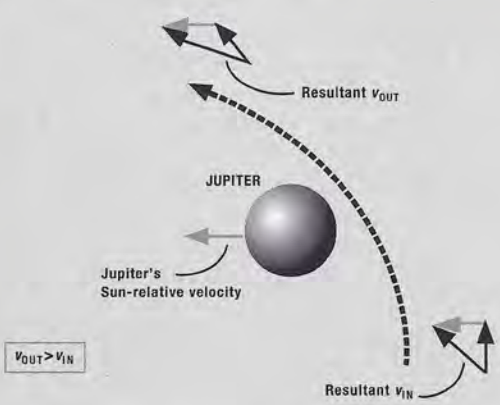


***Figure 2.** Jupiter is moving with respect to the Sun, and the spacecraft acquires some of Jupiter's velocity through mutual gravitational attraction. The result is that the magnitude of its outbound velocity, v_{OUT}, exceeds that of its inbound velocity, v_{IN}, relative to the Sun.*

All masses attract each other. Jupiter attracted *Voyager* to itself, and at the same time *Voyager* attracted Jupiter to itself by an infinitesimal amount. This caused Jupiter to slow down ever so slightly in its orbit about the Sun. In the trade-off, *Voyager* gained some of Jupiter's angular momentum—its orbital velocity—which caused it to accelerate enough, as viewed from the Sun, to fly to Saturn, where the same kind of gravity assist was repeated for the flight to Uranus. (Figure 2 shows the gravity-assist vectors.)

Gravity assist can slow you down, too. It all depends on the way the spacecraft is aimed as it passes the planet. If you approach Jupiter from behind the planet in its solar orbit, as *Voyager* did, some of Jupiter's orbital velocity is added to the spacecraft, and the spacecraft receives a boost. On the other hand, if you fly more in front of Jupiter in its orbit, your spacecraft pulls Jupiter slightly in the other direction, causing the planet to speed up ever so slightly and causing momentum to be taken from the spacecraft, slowing it down.

This is what happened with *Voyager* at Neptune, a side effect of targeting for Neptune's moon Triton. It is what *Galileo* will do intentionally when it encounters Jupiter's moon Io this December: Flying a gravity-assist trajectory that takes the spacecraft in front of Io in its jovian orbit, *Galileo* will slow down a bit, saving some propellant as it enters jovian orbit.

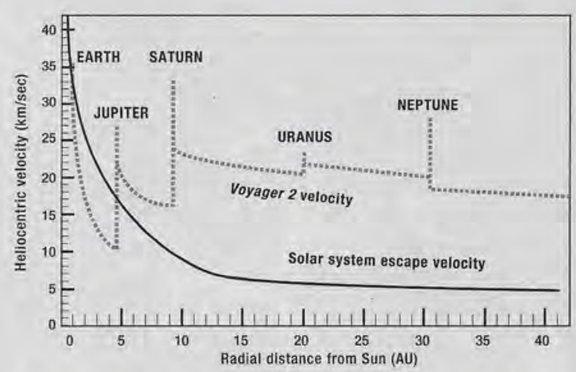


***Figure 3.** Voyager 2's speed relative to the Sun increased and decreased at each planetary encounter, and the spacecraft left each encounter (except with Neptune) with more speed than it had coming in. After passing Jupiter, Voyager had enough speed to leave the Sun's gravity forever, as seen by the solar system escape velocity, also plotted here. (An AU, or astronomical unit, is roughly 150 million kilometers or 93 million miles.)*

Figure 3 shows *Voyager 2*'s speed throughout its tour. It might be interesting to muse that if you were flying on *Voyager* as its passenger, you would never notice any sense of acceleration due to the encounters with the planets, even though your speed increases dramatically. Your only sensation would be the continuous "zero G" of free fall. Well, OK, you would feel the cold and deadly vacuum of interplanetary space!

Here are the questions we'll address in the next issue: How do you tell exactly how fast an interplanetary spacecraft is going? How do you make it go where you want it to go?

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

Rover Meets Jason: Remotely Exploring Hawaii

by John Garvey

In the latest and most ambitious Mars Rover field tests to date, team members from NASA, McDonnell Douglas Aerospace, Russia's NPO Lavochkin and Space Research Institute, and The Planetary Society worked with representatives from the Jason Foundation on a series of experiments on Hawaii's Kilauea volcano. From early February through mid-March, we drove a rover equipped with new avionics supplied by NASA Ames Research Center and McDonnell Douglas across Kilauea's lava flows.

In the first set of tests, we remotely operated the rover near the primary Kilauea caldera at an altitude of 4,000 feet. Planetary scientists across the Pacific at Ames in Moffett Field, California, drove the vehicle for some 36 hours over six days, simulating first martian and then lunar modes of operation. At test sites chosen for their resemblance to the terrain of the Moon and Mars, scientists used the rover to explore the volcanic landscape as if it were an alien world.

The United States Geological Survey's Hawaii Volcano Observatory and the National Park Service played key roles in making these tests possible—they provided access authorization, specified environmental protection procedures and gave the team free use of their facilities. EDS (Electronic Data Systems) and other Jason partners supplied critical telecommunications support.

Upon completing the science tests, the rover team shifted to supporting the Jason expedition to Kilauea. The Jason Foundation for Education is a nonprofit organization founded by Robert Ballard, developer of the original *Jason* robotic submersible and discoverer of the *Titanic*. The foundation annually conducts a two-week-long expedition to scientifically interesting locations around the world, during which students at Primary Interactive Network (PIN) sites interact with the site team in real time.

In this, the sixth such Jason expedition, 27 PIN sites participated in 60 separate hour-long broadcasts from Kilauea. Fresh lava flows were always in sight and at times directly affected broadcast operations. Between 300,000 and 400,000 students witnessed the rover tests from PIN sites in the US, Canada, Mexico, Bermuda and the United Kingdom, thanks again to EDS, the Williams Company (which provided the digital data network and associated software) and other Jason sponsors. Planetary Society members were able to witness the tests and take part in educational activities through events hosted by the PIN sites. More than 80 students actually controlled the vehicle using PC-based software developed by McDonnell Douglas. On March 2, Charles Gibson of *Good Morning America* drove the rover live, before millions of TV viewers.

These broadcasts demonstrated that the technology and the audiences are in place for live public interaction on planetary missions. Rover team members are now reviewing the results of the tests and refining future test plans.

John Garvey is manager for planetary systems at McDonnell Douglas Aerospace.

Above: The Mars Rover tackles the lava fields of Kilauea. Right: Children in Hawaii control a model Lego rover traversing a simulated Mars terrain set up in Los Angeles.
Photos: Laszlo Keszthalyi, above; Susan Lendroth, right.

Red Rovers: An Absolutely Phenomenal Success

While the Mars Rover team pitted its robot against the lava fields of Kilauea, an equally exciting test was taking place: the Society's Red Rover, Red Rover Lego project.

This winter, four student teams—in Toronto, Ontario; Logan, Utah; Los Angeles, California; and Hilo, Hawaii—began to explore Mars. Their mission was to construct martian terrain, design and build rovers, and control these rovers by computer. They worked toward the date of February 16, when the four sites would link up.

The project grew out of a program devised by Sheila Rhodes of the Ontario Science Center, where children built Mars rovers from Lego Dacta kits. Seeing this at the National Conference of Challenger Centers' Faculty, Society Executive Director Louis Friedman suggested adding the element of teleoperation.

Each student group investigated martian geology and built a realistic terrain. Using kits on loan from Lego Dacta, the students studied mechanics in order to design and build a rover that could explore their terrain. Utah State University provided control software and small cameras for the rovers—"eyes" for navigation across the simulated landscape—and computer control stations to receive images from the cameras and transmit commands to the rovers.

In a couple of months of intense work, the students simulated the development of a real planetary mission. Then, on February 16, the team at the Ontario Science Center took command of the rover at Utah State, whose team returned the favor. From the Challenger Boys and Girls Club in South Central Los Angeles, commands went out to the rover at the Kaiko'o Mall in Hilo. The Hawaiian team, in turn, drove a rover through Mars in Los Angeles.

Everything worked. It was "an absolutely phenomenal success," according to Society Resource Center Manager Kari Magee. We are all so pleased with the results and with the students' enthusiasm that we are making this into a permanent program. Our longtime associate and special consultant George Powell, now at the Jet Propulsion Laboratory, has agreed to manage the new project.

After the tests, Hilo teacher Dale Olive commented that in the future teachers will be facilitators of learning rather than sources of information. He said that the Red Rover, Red Rover project was a perfect example of this. In that spirit, the Society has taken up this commitment to children and the future.

—*Charlene M. Anderson, Director of Publications*

World Watch

by Louis D. Friedman

Washington, DC—The chart on this page shows the president's proposed budget for NASA in each fiscal year from 1993 to 1996, projected through 2000. When the budget is requested by the president and approved by Congress, it includes a five-year projection so that programs approved in the current fiscal year can plan on funding in the future. In addition, allowances are made for new starts under consideration in the planning phase.

As the chart shows, budget projections have decreased substantially. Looking at the projection for the year 2000 that was made in fiscal 1993 versus what's being made in fiscal 1996, we see a decrease of about 36 percent. NASA's program is projected to be almost cut in half from what was being planned six years ago.

The chart clearly shows that NASA has become a leaner agency, capable of accomplishing more with a smaller budget. NASA has already made the post–Cold War adjustment and dealt with new budget realities. We hope this is kept in mind when further cuts are being considered in the new Congress.

Paris—The European Space Agency has formulated a 10-year plan called Horizon 2000 Plus to deal with science and exploration missions beyond 2006. It is designed as a rolling program, thereby ensuring continuity and coherence with the objectives of Horizon 2000, ESA's earlier plan.

InterMarsNet, the European Mars mission being developed in cooperation with NASA, is part of Horizon 2000. Its *Ariane* launch will be in 2003, if the mission is approved.

Rosetta, the comet rendezvous mission, is part of the current plan. It also has a launch date of 2003. In addition to the ESA spacecraft, the mission will include one surface lander to be built by NASA and CNES (the Centre National d'Études Spatiales), and another to be built by Germany.

The new plan calls for the development of a major (cornerstone) scientific mission to Mercury. Also proposed is participation in such international endeavors as a new medium-class mission to Mars, solar missions, and missions related to the space station.

In the area of astronomy, the ESA plan calls for a cornerstone-level program whose primary aim will be to perform astrometric observations, including searching for planets around stars in our galaxy.

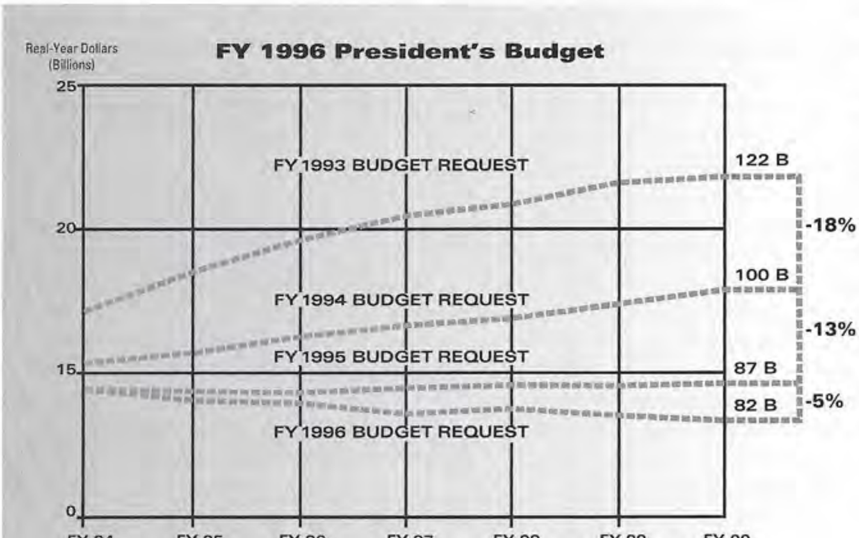
In this plan, ESA's science budget will be held at its 1994 level until 2000, when it will be increased by 4 percent to 5 percent per year for four to five years.

Houston—More than 800 scientists attended the Lunar and Planetary Science Conference here in March. The presentation of new *Clementine* results generated a lot of enthusiasm and interest in the Moon.

Plans for the Discovery program's newly selected Lunar Prospector mission were outlined by its principal investigator, Alan Binder of Lockheed Martin Corporation. University of Hawaii scientist Jeffrey Taylor discussed the Hawaii lunar and Mars rover tests, in which the Society was involved. (See page 16.) Another Society program was given attention at a session on Chicxulub (the probable site of the comet or asteroid impact 65 million years ago that led to the extinction of the dinosaurs). The session was co-chaired by Society special consultant Adriana Ocampo, a Jet Propulsion Laboratory scientist whose work on identifying and characterizing the site has been so important.

New results from the analysis of meteorites believed to be fragments of Mars were revealed at the conference. They indicated the presence of organic material (known as polycyclic aromatic hydrocarbons). The existence of underground water on Mars was given support from measurements on the meteorites that evidenced past hydrothermal activity and showed high carbonate activity—carbonates indicate carbon dioxide having dissolved in water.

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



NASA budget projections for fiscal years 1994 to 2000, based on amounts requested by the president in each year from 1993 to 1996. Totals on right are given in billions of dollars. The 1995 and 1996 budget requests show actual values appropriated for earlier years.

Chart from NASA, redrawn by B.S. Smith

News and Reviews

by Clark R. Chapman

About two decades ago, a colleague of mine at the Planetary Science Institute came in one Saturday to use our computer. But it wasn't there. Gone. Mysteriously, it reappeared Monday morning, hooked up and ready to compute. It seems that our computer guy had carried off our Hewlett-Packard to Bisbee, Arizona, to help him with his duties as official timekeeper for the annual Bisbee bicycle race.

We later scolded our assistant, an irrepressible planetary science graduate student named Cliff Stoll. Since then, Stoll got his PhD, wrote his best-selling computer spy thriller, *The Cuckoo's Egg,* and has just come out with a second book, *Silicon Snake Oil* (Doubleday, 1995, $22.00).

How could Stoll carry away the computer of a scientific research establishment? Today it would be impossible: Our network of work stations snakes through most offices in our building. Back then, desktop computers were in their infancy. For serious number-crunching, we bought time on the old "mainframe" at the university. But we made the best use we could of our $15,000 stand-alone H-P, though it was little more than a glorified calculator, well suited to timing bike races.

Surfing the Internet

Today, computers and the Internet have become an integral part of the lives of most scientists. Increasingly, they invade the lives of most readers of *The Planetary Report,* and the public generally. I'm only partway along the on-ramp of Al Gore's (or Newt Gingrich's) vision of our future on the information highway. True, most of my correspondence, business and personal, is via e-mail. Otherwise I use fax or Federal Express, while snail-mail accumulates, unread (unless it looks like a check) in piles on my office floor.

Like Stoll, I marveled at images of comet Shoemaker-Levy 9's crash last summer, piped—albeit slowly—over the World Wide Web from the far corners of the Earth. And I'm writing this column, as I have done for years, on my latest laptop computer, which rarely leaves my side. But Unix is a foreign language to me. I've never loitered in a newsgroup. And surfing the Net is a recreation as remote from my life as visiting the local bowling alley.

Computers are good for some things, but they are poor substitutes for many others. Before we get caught up in the virtual reality of cyberspace, we should examine just how ineffective and shallow much of today's computerized reality really is. That's the message of Cliff Stoll's book, which is subtitled "Second Thoughts on the Information Highway."

Knowledgeable Naysayer

There have been many naysayers about the computer revolution, but few are as knowledgeable as Stoll. He has lived and breathed computers from an early age, he *has* surfed the Net, and he knows whereof he speaks. He longs for the old-fashioned rocking chair chats with neighbors on a summer's evening.

Stoll is a natural storyteller: You're practically there with him on his porch. His loosely organized stream of opinions and insights about the new information age is cobbled together with anecdotes from his life as a planetary astronomer. *Silicon Snake Oil* is an easy read. Its conclusions are disturbing. Like television, the Internet is a captivating technological advance that is becoming another vast wasteland. And it doesn't work very well, either. Like talk radio, the Net fosters a sense of selfish urgency with little content. Instead of buying computers for schools, Stoll thinks we should take kids into the fields to smell the flowers, explore the caves and learn about real life. It sounds conventional, but it is wisdom from someone who's been to cyberspace—and returned with his mind not yet numb.

Venus and Jupiter

I don't agree with all of Stoll's skepticism. His postcard experiment notwithstanding (he received *all* the cards his brother sent him), the United States Post Office is a scandal. I'm as frustrated by keyword searches in on-line library catalogues as is Stoll, but old-fashioned indices are worse ways to access information. *Snake Oil*'s index has amusing entries like "Recursion" (look it up), and Stoll was ahead of me when I skeptically sought out "Jumbo"—and found it (try it yourself). But serious subjects (like "comet") weren't there. Try to find Stoll's comparison of the Jet Propulsion Laboratory's colorized *Magellan* images of Venus to *Time*'s colorized mug shot of O.J. Simpson—it's not under "Venus" or "Simpson, O.J.," nor are pages 83–84 listed under "Image Processing."

As a Planetary Society member ponders Stoll's critique of the Internet, he or she will also be immersed in an astronomer's life. Reading *Snake Oil* is an easy way to visit the world of a student of science interested in the stars. Watch him fashion a thesis topic and attempt to decipher Jupiter's atmosphere. Then he matures and grows wiser.

Buried amid Stoll's musings about our computerized future is a startling critique of modern science. Not only is the Net consuming our disposable, recreational time, but the false sense of security scientists get from numerical answers and Photoshop presentations may be undermining the validity of our work. Stoll worries that his own thesis conclusions about Jupiter's atmosphere may have been a figment of his computer's imagination. His may not be an isolated case.

Clark R. Chapman is trying to gain access to the Web from his desktop. But he still hikes in the mountains with his wife, Lynda.

Society News

Our Commitment to SETI

Our support of the Search for Extraterrestrial Intelligence (SETI) has become ever more important since all government funding in the United States and elsewhere has ceased. Our main project remains BETA (Billion-channel Extraterrestrial Assay), which should replace our META (Megachannel Extraterrestrial Assay) search program at the Oak Ridge Observatory in Harvard, Massachusetts, later this year.

We also have recently given Ohio State University's "Big Ear" project a small grant for additional analysis of data collected during observations in 1977–1984. We had funded Robert Gray's search in the area of the sky where the famous "Wow" signal was received at Ohio State. Gray's confirmation search was conducted at Oak Ridge with the cooperation of Paul Horowitz, Society project director for META and BETA. No repeat of the "Wow" signal was found. For a copy of the scientific report on Gray's searches, contact the Society and ask for the "Wow" report.

We are considering providing a grant to help another full-time search program, SERENDIP, which is in danger of being lost due to lack of funds. This search, conducted at the world's biggest telescope, Arecibo, is the most sensitive search in the world. However, it has had to use whatever frequencies were, by chance, available. Now it has the opportunity to do the search at the 21-centimeter hydrogen wavelength. But it needs funds. Once we meet the requirement of getting BETA on-line, we'll try to help the SERENDIP program.

—Louis D. Friedman, Executive Director

Society History Made On-line

The Planetary Society's first two on-line computer conferences were conducted during the Mars Rover field tests in Hawaii earlier this year.

John Garvey of McDonnell Douglas Aerospace was the guest speaker at the first, held February 15 in cooperation with the Space and Science RoundTable on GEnie. David James, also of McDonnell Douglas, and Slava and Katya Linkin, of the Russian Space Agency, were guest speakers at the second, held February 20. Each guest provided an interesting commentary on the rover tests, including mission highlights and lessons learned.

Our Russian guests evaluated the Mars Rover, extensively modified by engineers from NASA Ames and McDonnell Douglas, relative to its performance in previous tests hosted by the Society. Transcripts of the conferences are available on GEnie. Future on-line conferences on a variety of topics are planned for the near future (see our GEnie RoundTable for updates). As we learn the ways of cyberspace, our online services will continue to improve. We encourage all members to join us on GEnie, and we welcome feedback on all our electronic activities.

—Kari Magee, Resource Center Manager

Join Us for Steps to Mars II

When the space shuttle docks with Russia's *Mir* space station in June 1995, it will mark the beginning of a new era of cooperation between the United States and Russia. Coincidentally, 1995 is also the 20th anniversary of another rendezvous in space, *Apollo-Soyuz*.

We'll celebrate both occasions on July 15, with our Steps to Mars II symposium at the National Academy of Sciences in Washington, DC. (At the first Steps to Mars conference, held in 1985 on the 10th anniversary of *Apollo-Soyuz*, Senator Spark Matsunaga proposed the International Space Year and the Society first advocated American-Soviet cooperation in robotic and human Mars exploration.)

The American Astronautical Society and the Association of Space Explorers will cosponsor Steps to Mars II. To learn more about the symposium and about how you can participate, please contact me at Society headquarters. My e-mail address is TPS.sl@genie.geis.com.

—Susan Lendroth, Manager of Events and Communications

Come to Our Dinner, Too

On July 14, The Planetary Society will honor the winner of the second Thomas O. Paine Memorial Award for the Advancement of Human Exploration of Mars at a very special dinner in Washington, DC.

Many leaders of the international space community will attend, and Planetary Society President Carl Sagan will present the award to the winner. Because the dinner will occur not long after the planned docking of the shuttle and *Mir,* we are working on a live hookup with members of the crew remaining in orbit, and/or attendance of crew members at the dinner. For information, please contact me at the Society. *—Diana Marquez, Director of Development*

Chips, Anyone?

Micron Technology, Inc., of Boise, Idaho, is very generously offering $100,000 worth of computer memory, 3,400 megabytes, to the Society—just the ticket for the next phase of our Search for Extraterrestrial Intelligence, BETA, which Project Director Paul Horowitz hopes to have operating this fall.

There's a condition. We need our members' help. Micron's donation is in the form of a matching-gift program: Micron will donate one dollar's worth of chips for every dollar you donate.

So please help BETA search the stars. Send your donation to SETI, c/o Society headquarters. Whatever you give, Micron will match in chips. *—SL*

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Questions and Answers

Are the apparent positions of meteor shower radiants due to Earth's orbital motion around the Sun? Why are radiants of some meteor showers—such as the Draconids, Lyrids and Ursids—not located on the ecliptic plane?
—Steven M. Huels, Dunkirk, New York

A meteor shower radiant is the point (actually a small patch) in the sky from which meteors belonging to a shower seem to radiate. When they collide with Earth's atmosphere, their trails can be traced back to the radiant. All the individual meteoroids in the parent stream have parallel orbits. In reality, the radiant is caused by a perspective effect, just like the one that makes railroad tracks appear to merge in the distance.

Almost all meteor shower radiants are off the ecliptic. This is primarily a reflection of the individual orbits of meteors in the showers. The only thing these orbits have in common is that they all intersect Earth's orbit. They can have any overall size, shape or orientation in space as long as they come near Earth's path around the Sun. This means that meteors radiate from the direction required by their orbits around the Sun.

A good analogy is a car moving slowly through wind-driven rain. When the car stops, the rain will strike it from some direction that can be identified against background landmarks or with a compass. When the car moves slowly, at a speed less than that at which the raindrops are falling (just as Earth moves more slowly than meteoroids in their orbits), the direction of the rain's radiant changes slightly depending on the direction of the car's motion. Even though the radiant changes, it is still close to where it was when the car was stationary. In fact, we can observe the motion of meteor radiants due to Earth's motion over the course of several days while a meteor shower is active (which means Earth is not too far from the intersection of its orbit and the meteor stream's orbit).
—STEVE EDBERG,
Jet Propulsion Laboratory

On November 17, 1966, one of the most spectacular meteor showers in recent history spangled the predawn sky. In this three-and-a-half-minute exposure of the Leonid meteor shower, two point meteors appear near the shower's radiant in the sickle of the constellation Leo. A point meteor is one which is seen by an observer directly in line with the oncoming particle. It's like looking down the barrel of a rifle with the bullet (meteoroid) coming straight at you. Point meteors show exactly where the radiant is.

Photograph: Dennis Milon

While wondering how, in the distant future, people in our solar system would communicate with a human colony in another solar system, I realized that any place on or near a line passing through the two solar systems would be a likely place to receive radio messages. Is this correct?
—Robert L. Schuman, Winthrop, Iowa

In 1961, SETI pioneer Sebastian von Hoerner classified intelligent extraterrestrial signals into three general categories: local communication on the other planet, interstellar communication with certain distinct partners and attempts to attract the attention of unknown future partners. He named these categories "local broadcast," "long-distance calls" and "contacting signals" (beacons).

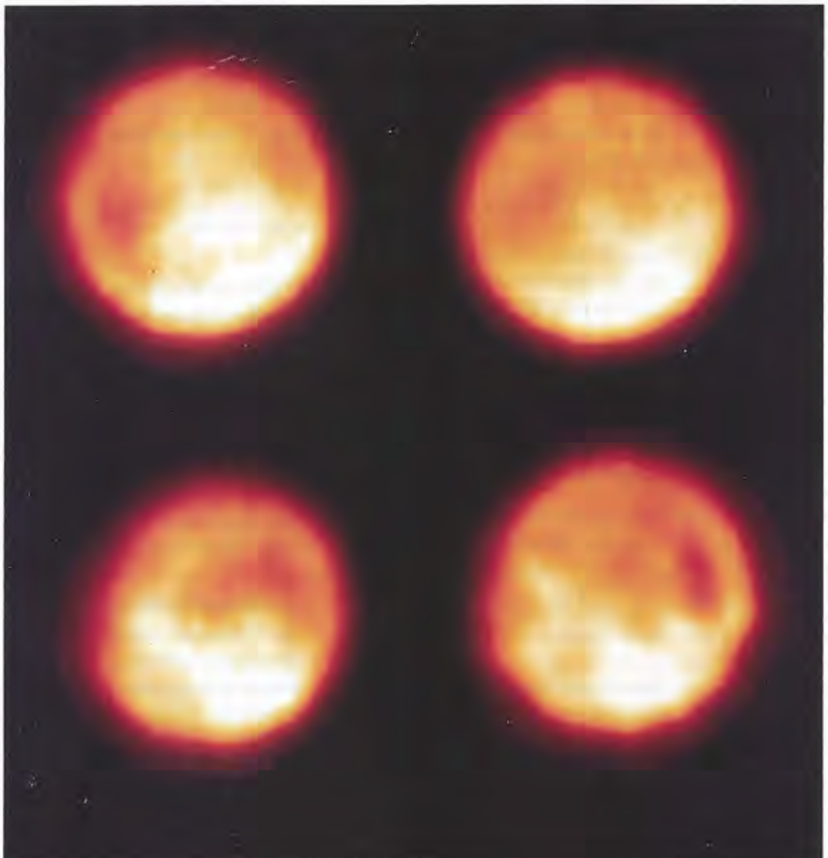
Considering the frequencies that were selected, the sensitivity and resolution of the equipment that was used and the observing strategies, most of the 60 SETI projects done in the past 30 years assumed that there are several extraterrestrial civilizations transmitting powerful interstellar beacons. The other main hypothesis that was used was that any possible message will be coded with the "anti-cryptographic principle" (the signals will be coded as simply as possible to allow for their correct interpretation by emerging societies).

What you are referring to is the second group of signals, the long-distance calls whose main purpose would be the exchange of information between the central planet and a hypothetical colony outside their star system. The characteristics of this kind of transmission would be very different from the ones we expect in our SETI research beacons. Because they know the position of their colony in space, "they" will concentrate the transmission energy to target only that stellar colony (high directivity). In this way they will maximize the quality of the transmission and reception. Because they already know each other, they will also know beforehand the exact transmitting frequency, which could be very different from the one that is expected for interstellar beacons. Because they want to exchange information, the bandwidth of their transmission will be very broad (in our SETI projects we search for ultra-narrowband signals). There is a good possibility that for this kind of communication they will use powerful nanosecond pulsed lasers (this system satisfies all the requirements that were mentioned). In this case, the communication channel would be optical rather than microwave.

The main disadvantage for a terrestrial observing team is that we would have to be in the exact line of sight that connects their central planet with their star colony. Considering the high directivity of this transmission, the probability of our intercepting it is negligible.
—GUILLERMO A. LEMARCHAND, *Argentine Institute for Radio Astronomy*

Why don't stars appear in photographs that astronauts take in outer space and on the Moon?
—Jim Snedeker, Williston, Vermont

Astronauts can see stars, and cameras can photograph them, in space when not too much light is present from bright objects in the foreground. But in daylight, sunlit areas (the Moon's surface, the shuttle or even the astronauts' space suits) cause eye pupils to contract and require cameras to be stopped down, so all but the brightest stars disappear.
—JAMES D. BURKE, *Technical Editor*



Factinos

With the help of NASA's Hubble Space Telescope (HST), a team of scientists has detected an extremely thin atmosphere of molecular oxygen around Jupiter's moon Europa. The researchers, from Johns Hopkins University and the Space Telescope Institute, both in Baltimore, reported their discovery in the February 23, 1995, issue of *Nature*.

"Europa's oxygen atmosphere is so tenuous that its surface pressure is barely one hundred billionth that of Earth," said the team's principal investigator, Doyle Hall of Johns Hopkins. "If all the oxygen on Europa were compressed to the surface pressure of Earth's atmosphere, it would fill only about a dozen Houston Astrodomes. It is truly amazing that the Hubble Space Telescope can detect such a tenuous trace of gas so far away."

The HST researchers cautioned that the detection should not be misinterpreted as evidence for the presence of life on the small, frigid moon. Unlike Earth, where living things generate and maintain a 21 percent oxygen atmosphere, Europa's oxygen atmosphere is produced by purely nonbiological processes.
—from NASA

Voyager 1 is currently 8.8 billion kilometers (5.5 billion miles) from Earth and is traveling at a speed of 61,200 kilometers (39,000 miles) per hour. *Voyager 2* is 6.8 billion kilometers (4.3 billion miles) from Earth and is moving at 57,600 kilometers (36,000 miles) per hour.

Both spacecraft are healthy and they are still making observations of their interplanetary environment.
—from the Jet Propulsion Laboratory

These images of Saturn's moon Titan (at left) were captured in December 1994 by a group of researchers at the University of Hawaii's Institute for Astronomy. A bright, continent-sized feature is clearly visible in the moon's southern hemisphere.

The team used the Canada–France–Hawaii telescope and a system called "adaptive optics" to take these ground-based images. Adaptive optics is a method of real-time compensation for image degradation due to atmospheric turbulence. (See Factinos in the January/February 1995 *Planetary Report* for a similar set of Titan images returned by the Hubble Space Telescope.)
—from the University of Hawaii

Image: François Roddier, Jim Anuskiewicz, J. Elon, Malcolm Northcott and Claude Roddier/University of Hawaii

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Ever hopeful, we on Earth are refining the search for other sentient beings in our galactic neighborhood. "The Whirlpool" depicts the brilliant, swirling center of our Milky Way galaxy. The core's nucleus, as it appears here, is somewhat elongated, based on the latest astronomical studies.

Joe Tucciarone, who has a master's degree in physics and astronomy, is a member of the board of the International Association for the Astronomical Arts. His work has appeared in *National Geographic*, *Sky & Telescope*, and numerous planetarium shows throughout the world for over 20 years.

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