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Imaging Io

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COVER: Surface variations on volcanic Io are exaggerated in this Voyager false color image of Jupiter's volcanic satellite. By manipulating digital images returned by spacecraft, scientists can bring out details of planets and moons not always visible in a scene as the human eye would see it. This Voyager image is a Mercator projection of part of Io's surface.

IMAGE: ALFRED McEWEN/UNITED STATES GEOLOGICAL SURVEY

Letters to the Editor

We encourage our members to write us on topics related to the goals of The Planetary Society: continuing planetary exploration and the search for extraterrestrial life. Letters intended for publication should be short and to the point. Address them to: Letters to the Editor, P.O. Box 91687, Pasadena, CA 91109.

Your new stress on the international scope of the Society has made a deep impression on me. As a foreign language teacher with a strong commitment to international global awareness, I welcome all cooperative efforts to unite, eliminate duplication, and explore together. I endorse especially space exploration undertaken on a cooperative basis, between NASA and the European Space Administration.

RAYMOND J. CORMIER, *Temple University, Ambler, Pennsylvania*

Your special issue on asteroids [July/August, 1983] was most informative. I am proud to be part of such an exciting and dynamic organization. It's great to know that the solar system is not seen as a potential battlefield by all. Keep up the good work!

SHEILA JABALPURWALA

Even though I am a biologist and belong to a number of professional societies, I feel an unusual sense of participation and satisfaction in my membership in The Planetary Society. My professional societies serve to provide me with a forum for secular exchange through journals and public meetings. They lobby the government to maintain research support but rarely do they reach the general public. Rarely do they communicate the excitement and wonder of our scientific pursuits. Never do these societies involve their own membership in a collective quest.

But The Planetary Society is refreshingly different. Imagine being a participant in a project to map the shape of a distant asteroid (The Pallas Project). [*See the March/April 1983 issue of* The Planetary Report.] How many of us have contributed recently to support a project that has as its only goal the "mere" acquisition of evidence for extraterrestrial life? Project Sentinel is no crackpot endeavor but a carefully and logically designed program. Our Society does not sit around and bemoan the paucity of government dollars extended to the study of our solar system. While fighting to save the government program on the one hand, it is committing dollars and manpower with the other to support research. In a a real sense we can all share in her achievement every time Eleanor Helin announces the discovery of another asteroid.

I hope in the near future to read in the pages of *The Planetary Report* how we can become involved in studies of Halley's Comet. (Is it really possible that the United States will not mount an encounter mission?)

Perhaps my enthusiasm for The Planetary Society stems from something more than its earthly successes. Perhaps it is a chance to become involved with something truly cosmic.

DONALD A. McAFEE, Ph.D., *Beckman Research Institute of the City of Hope, Duarte, California*

A few days ago, I finished reading the September/October 1983 issue of *The Planetary Report.* I usually do not write to magazines, but this one was special.

I've been reading the *Report* since Volume I, and from what I have read thus far, I can definitely say that "The Last *Viking*" was the single most outstanding article you have ever run. It was extremely well-written and the issue's cover complemented it beautifully.

"The Last *Viking*" read more like a story than an article, primarily because *Viking* Lander 1 *was* more than a piece of equipment. Jonathan Eberhart should be commended for capturing this feeling.

It is the gift of humanity to dream, and the *Viking* landers carried our dreams to their destinations. Lander 1 was more of an innocent child far away from home than a $1 billion piece of scrap metal. May it never be said that *Viking* was just a machine.

PAUL D'AMICO, *Saddle Brook, New Jersey*

PROJECT SENTINEL TO GROW

by Thomas R. McDonough

Project Sentinel, The Planetary Society's major project in the Search for Extraterrestrial Intelligence (SETI), is being greatly expanded. The membership-supported research is already the world's most advanced SETI (rhymes with "jetty") project currently operating, but the planned expansion will make it sixty-four times more powerful.

At the annual meeting for the Division for Planetary Sciences of the American Astronomical Society held at Cornell University in October, 1983, the announcement was made by Carl Sagan, President of The Planetary Society, and Paul Horowitz, the Harvard physicist who designed and built Sentinel. The expansion has been given its own name, META, for Megachannel Extraterrestrial Assay.

META, to be completed this year, will allow the SETI project to observe 8.4 million channels at a time. "META makes the system the biggest analyzer on Earth. It allows us to detect an extraterrestrial civilization that is not beaming a signal specifically to us," Professor Horowitz said.

The fundamental problem of SETI is that it is difficult to cover all potential radio channels, all parts of the sky, and all reasonable signal strengths. To accelerate the search, we must try to anticipate the types of signals that might be transmitted. The first assumption most SETI programs make is that aliens have built radio beacons to let other civilizations know of their existence. (Ordinary signals such as Earth's television and radar would probably be too faint to detect with present techniques.)

In Project Sentinel we try to deduce which radio channels they might use. Fortunately, there are certain channels that atoms and molecules of our Milky Way galaxy normally broadcast on—the "magic" frequencies. We suspect that an alien civilization that wanted to make itself known to others would broadcast on or near one of these distinctive channels. Sentinel is currently tuned to the strongest of these, the hydrogen signal at 1420 megahertz. An alien beacon might send an extremely carefully tuned (ultra-narrowband) signal near this frequency, because such a signal would stand out amidst the nearby natural hydrogen radiation and the general galactic noise.

But our troubles are not over even if we have chosen the right magic frequency. The problem is that everything in the universe is moving, and any signal will be changed by the transmitter's motion toward or away from us, a phenomenon known as the Doppler effect. For this reason, a signal transmitted on one radio channel is received on a different one. In Project Sentinel, we assume that the aliens have corrected for the change due to their motion toward or away from our Sun. However, it is conceivable that they might instead decide to shift transmissions to the same channel that signals from the center of the Milky Way would be on, or even to the channel corresponding to the center of the universe, both of which are outside the current range of Sentinel. Project META will allow us to detect them if they have chosen either strategy.

It is only lately that humans have been able to measure our motion through the universe as a whole—to determine the "rest-frame of the universe." This came about because astronomers recently measured precisely the cosmic radio noise left over from the Big Bang that gave birth to the universe. They found a slight Doppler shift in this noise, which told us for the first time how fast we are moving through the universe. This leads to the possibility that an alien civilization might shift its transmitter to the channel that hydrogen would broadcast on if it were standing still in the universe, because this may be the most fundamental of all frequencies. Now we know our cosmic velocity accurately enough to allow META to tune to this cosmic magic frequency.

It was Society Advisor Philip Morrison, together with Giuseppe Cocconi, who first suggested in 1959 that other civilizations might communicate using the magic frequency of hydrogen. Morrison suggested to Horowitz last year that the rest-frame of the universe gives us the "magic frequency of all magic ones."

The scientific research that uncovered this fundamental knowledge about the universe has paralleled the technological revolution that gave us the powerful, inexpensive electronics. The revolution that gave us the microchips in our digital watches now allows us to make this great advance in our search for extraterrestrial neighbors. The plummeting cost of the technology has made it possible to build an eight-million channel receiver for the relatively modest sum of about $100,000—an idea which would have been inconceivable just ten years ago.

Other SETI projects are underway in the US, the USSR and other countries. For example, NASA is also building an eight-million channel receiver which will eventually be even more powerful than META. It will scan the whole radio spectrum from 1000 to 10,000 megahertz, instead of just the magic frequencies. However, NASA hopes to begin operating in about five years, whereas Project Sentinel is actually running at this moment, patiently peering into space for the signals that may one day tell us that we are not alone in the galaxy.

Our search fits in with the SETI program endorsed a year ago by 70 scientists around the world, including seven Nobel laureates. Their petition, initiated by Carl Sagan, appeared in the journal *Science* on October 29, 1982 (reprinted in *The Planetary Report,* March/April 1983, page 11). The group proposed "a coordinated, worldwide and systematic search for extraterrestrial intelligence" to look for radio signals from elsewhere.

This year, the world's most advanced operational search for extraterrestrial civilizations will take a giant step. Soon, we shall tune to the magic frequency of the universe for the first time. And all because you, our members, made it possible.

Thomas McDonough is the SETI Coordinator for The Planetary Society and a Lecturer in Engineering at the California Institute of Technology.

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BY KEAY

The search for extraterrestrial intelligence (SETI) was born in the early 19th century to answer a long-standing question: Is there intelligent life on other planets? "Yes," a few ancient Greeks had replied. But virtually all medieval scholars regarded Earth as the sole inhabited world—it was the center of the cosmos; around it orbited the heavenly bodies, embedded like gems in crystalline spheres. The "Copernican Revolution" of the 16th and 17th centuries smashed that cozy cosmology. Telescopes revealed that nearby planets are solid worlds like Earth, and that stars are distant suns—possibly with planets of their own. And inhabitants? Few astronomers of the 18th century doubted it. Surely (they reasoned) God wouldn't create all those worlds, then leave them untenanted.

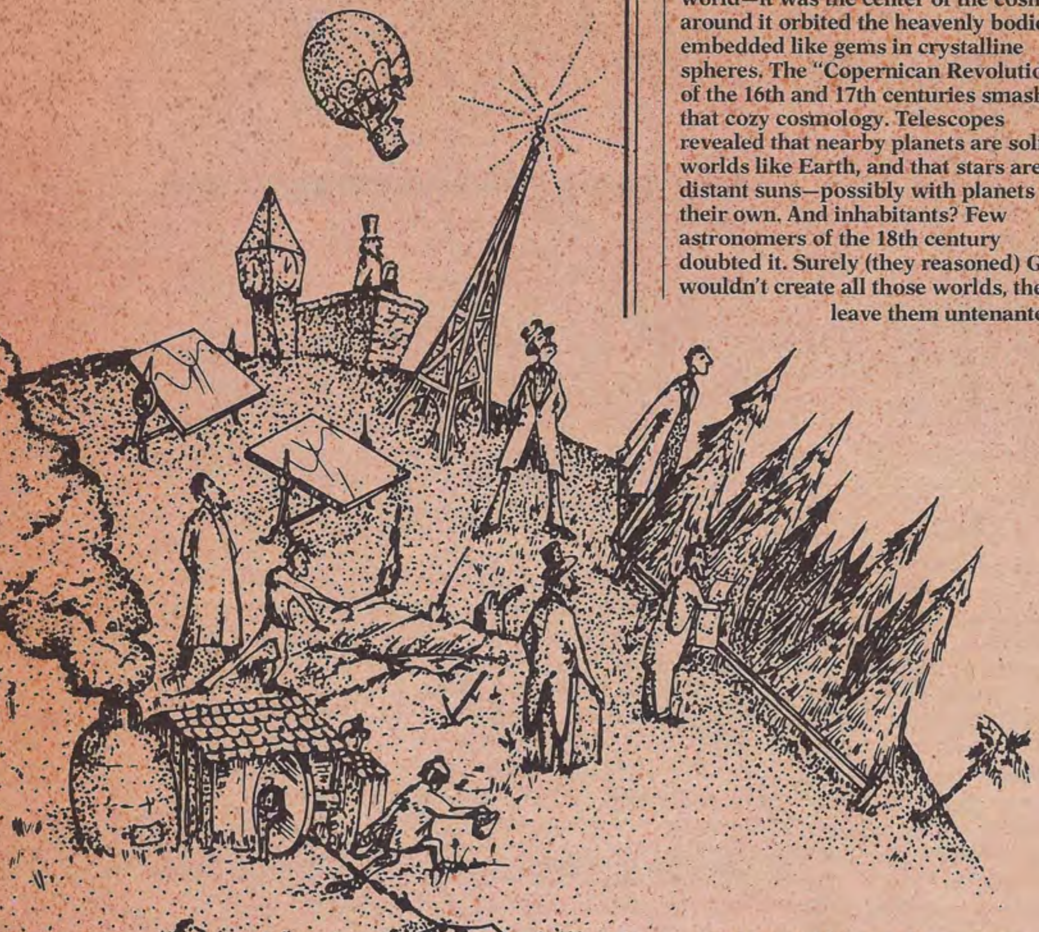

ILLUSTRATION: S.A. SMITH

Which raised the next question: Could we talk to the tenants, or they to us? In the 1820's the famed mathematician Karl Friedrich Gauss proposed saying "Hello" to beings on the Moon or planets by planting pine trees in Siberia in the shape of a huge Pythagorean triangle. Gauss had imitators. In 1840 the astronomer Joseph Johann von Littrow of Vienna proposed building an interplanetary signal-flare by pouring water into a 20-mile-wide ditch in the Sahara, then adding kerosene and lighting it. Another visionary wanted to erect giant mirrors across Europe. More mundanely, physicist Robert W. Wood proposed draping a large black cloth on white alkali plains and moving it back and forth with electric motors and cylinders. From Mars, the plains would seem to "blink."

In fact, Mars was SETI fans' brightest hope at the turn of the century. The astronomer Percival Lowell was making headlines with his theory that apparent "canals" on Mars were built by Martians to transport water across their dry planet. When Mars was in opposition, some astronomers reported seeing strange lights on the planet. Newspapers proclaimed that these were Martian "signals."

According to the celebrated scientist Francis Galton of England, pictures could be transmitted to Mars in coded form. Galton, a cousin of Charles Darwin, described how three types of flashed signals (which he called "dot," "dash" and "line") could be used as a code to transmit coordinates for a picture—say, of North America.

All these 19th century schemes involved massive, costly construction projects that would have rivaled that of the Panama Canal. Naturally, some scientists dreamed of a more practical means of interplanetary communication. It might come in a few centuries through "a new and unexpected discovery," the French astronomer Camille Flammarion wrote in 1892.

In fact it came within a decade, and it was called radio. The English astronomer Sir Robert Ball scoffed at the notion of radio communication across interplanetary space. Ball said radio waves would disperse uselessly into space unless concentrated in a tight beam by a transmitter "sixteen million times as efficient" as that foreseen by even the "most ardent champions" of radio. (Nowadays, of course, space probes routinely transmit images from distant planets. It's risky to be skeptical in forecasting the progress of technology!)

In the 1920's, newspapers reported that Guglielmo Marconi, the inventor of radio, thought he had detected Martian signals on his equipment. Earth

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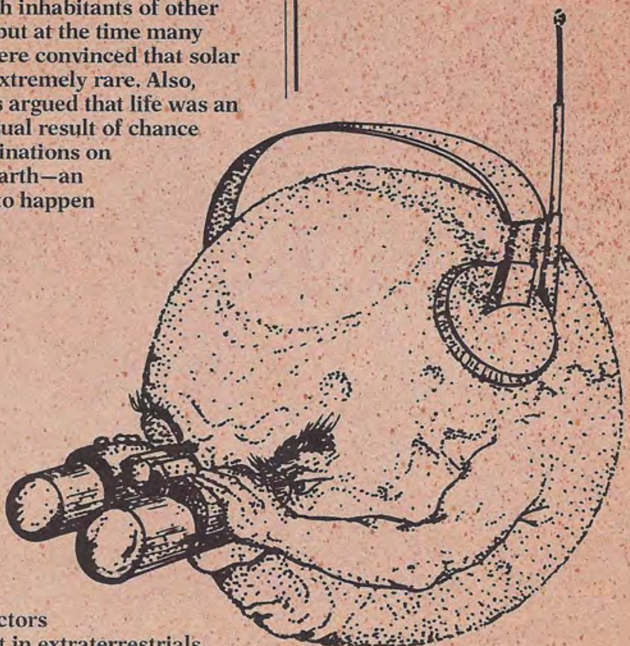
should reply, asserted the electrical pioneer Charles Steinmetz, who told a New York audience: "If the United States should go into the effort to send messages to Mars with the same degree of intensity and thoroughness with which we went into the [First World] war, it is not at all improbable that the plan would succeed."

The astronomer David Todd (an old colleague of Lowell) actually persuaded the US government to listen for signals from Mars during an opposition in August, 1924. The Chief of Naval Operations and the Army Chief Signal Officer ordered stations under their command to abide by Todd's request. The Army even appointed a code expert to decipher any Martian tidings. A few odd signals were heard. Television pioneer C. Francis Jenkins of Washington, D.C. recorded the signals on a moving roll of film and reported that they formed a crude human face. It all turned out to be interference from earthly radio stations.

Meanwhile, there was a new worry. There was evidence that radio signals bounced off an ionized region (the Heaviside layer) of the Earth's atmosphere. Could the Heaviside layer block the escape of radio signals from Earth to Mars, or prevent Martian signals from reaching here? The possibility gave Robert Goddard an additional excuse for designing an interplanetary rocket. Noting in 1920 that radio signals might be blocked by the Heaviside layer, he proposed using a rocket for interplanetary communication instead.

Obviously the Heaviside layer, which reflects only a certain band of radio frequencies, hasn't prevented us from communicating with spaceships. But after the 1920's, hopes of interplanetary communication faded. There were several reasons. For one thing, most astronomers thought (correctly) that the Martian "canals" were optical illusions. Other planets also appeared inhospitable to advanced life.

That left open the possibility of communication with inhabitants of other solar systems, but at the time many astronomers were convinced that solar systems were extremely rare. Also, some biologists argued that life was an extremely unusual result of chance chemical combinations on the primeval Earth—an event unlikely to happen elsewhere.



But in the 1950's, three factors revived interest in extraterrestrials. Scientists began developing a new version of the old nebular hypothesis which generated solar systems as the rule rather than the exception. Also, Stanley Miller's biology experiments indicated that amino acids, the building blocks of life, formed easily from chemicals in lab simulations of the early Earth. Finally, the space age opened with the *Sputnik* launch in 1957.

The turning point came in 1959, when *Nature* published an article by American physicists Giuseppe Cocconi and Philip Morrison. They proposed using radio telescopes, products of work by Karl Jansky and Grote Reber in the 1930's and 1940's, to detect extraterrestrial signals. At about the same time, Frank Drake of the National Radio Astronomy Observatory at Green Bank, West Virginia was planning just such a use for the 85-foot Green Bank radio telescope. He called it Project Ozma, "for the princess of the imaginary land of Oz—a place very, very far away, difficult to reach and populated by exotic beings."

In early 1960, Drake listened for signals from two stars, Tau Ceti and Epsilon Eridani. Nothing of interest was discovered. But the modern age of SETI had begun.

Keay Davidson is the science and medical writer for the San Diego edition of the Los Angeles Times.

Imaging—Pixels, not Pictures

by Alfred S. McEwen and Laurence A. Soderblom

Sunset on Mars, the elegant rings of Saturn, Jupiter's majestic face—all these alien vistas have been seen by millions on Earth through pictures returned by our exploring spacecraft. These are not photographs taken with camera and film, but "images" constructed by scientists using electronic data collected by a spacecraft "imaging system" and transmitted back to Earth. These images not only astound us with the beauty of other worlds, but teach us much about our neighbors in the solar system.

Astronomy has traditionally been a science based on visual observation. Ptolemy and Copernicus based their world systems on only the stars and planets bright enough to be seen by the naked eye. Galileo took the invention of a Dutch optician and made the telescope the primary tool of astronomers; his scientific descendants have become adept at using the light-gathering ability of their telescopes and the sensitivity of photographic film to reveal wonders of the universe invisible to the unaided eye.

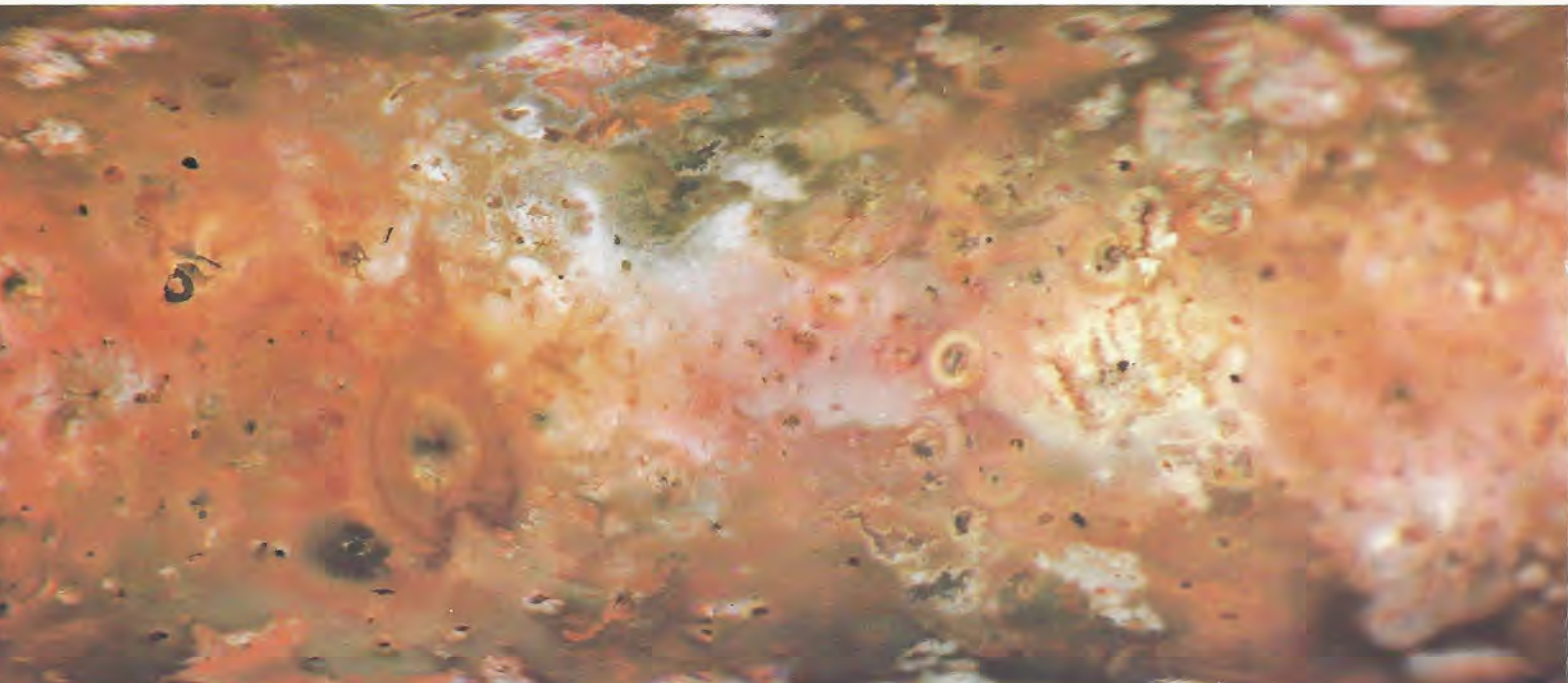
This technique has been spectacularly successful, but how could scientists get photographs from spacecraft hurtling through space at tens of kilometers per second? (Fotomat does *not* pick up and deliver!) Astronauts and cosmonauts took snapshots and brought the film back for processing, but *Mariner, Pioneer, Viking* and *Voyager* will never return to Earth (unless some future explorers pick up the old derelicts and carry them home). How, then, have these spacecraft sent us such spectacular pictures, and how have we learned so much about these alien worlds by simply looking at their faces?

In this article, we take a look at how the process of imaging has revolutionized our ideas about Io, Jupiter's volcanic moon.

Among the great discoveries of the *Voyager* missions were the sulfurous volcanos of Io. In Earth-based telescopes, Io appeared as a brilliant orange-yellow ball, but the satellite was too far away to be more than a colored point of light. But the *Voyager* spacecraft traveled more than a thousand times nearer to Jupiter than does Earth, and *Voyager 1* passed ten thousand times closer to Io. Their television cameras saw Io as a multihued disc, with white, yellow, orange, red and black patches, looking to some like a pizza with everything on it.

In one of the images returned by *Voyager 1,* navigation team member Linda Morabito saw what looked like a volcanic plume rising above the limb (apparent edge) of Io. Checking back over other images of the moon, project scientists discovered other volcanic eruptions captured by the spacecraft as it sped by. From the data from *Voyager's* cameras, Io was revealed to be the most volcanically active body known in the solar system.

The *Voyager* spacecraft each carry two television cameras, one with a wide angle of view and one narrow angle. The narrow-angle camera has 7.5 times the resolving power of the wide-angle, but the wide-angle can see an area 56 times larger. Each camera carries a rotating filter wheel to select the color of light to be seen by the cameras. They record individual images in blue, green, orange and



clear (all colors) and ultraviolet (narrow-angle camera only) light reflected off objects. By manipulating and studying the colors, or spectral properties, scientists can learn much about the circulation of atmospheres and the composition of surfaces. This process of "imaging" is a powerful tool for planetary scientists.

The "pictures" returned by a spacecraft such as *Voyager* are not made with photographic film. Light enters a television camera and is encoded as a series of 1's and 0's. These digital data, in the form of electronic impulses, are transmitted back to Earth on the spacecraft's radio link. The billions of bits (binary digits) of data making up the images can be processed and manipulated by a computer. A digitally-recorded image can be thought of as a large, two-dimensional checkerboard where each square represents a spot on the target body's surface. These individual spots, called picture elements ("pixels" for short), are assigned numerical values representing the recorded brightnesses of a scene. This technology is "digital image processing." In the last two decades, advances in image processing have been rapid, chiefly due to impetus from planetary exploration.

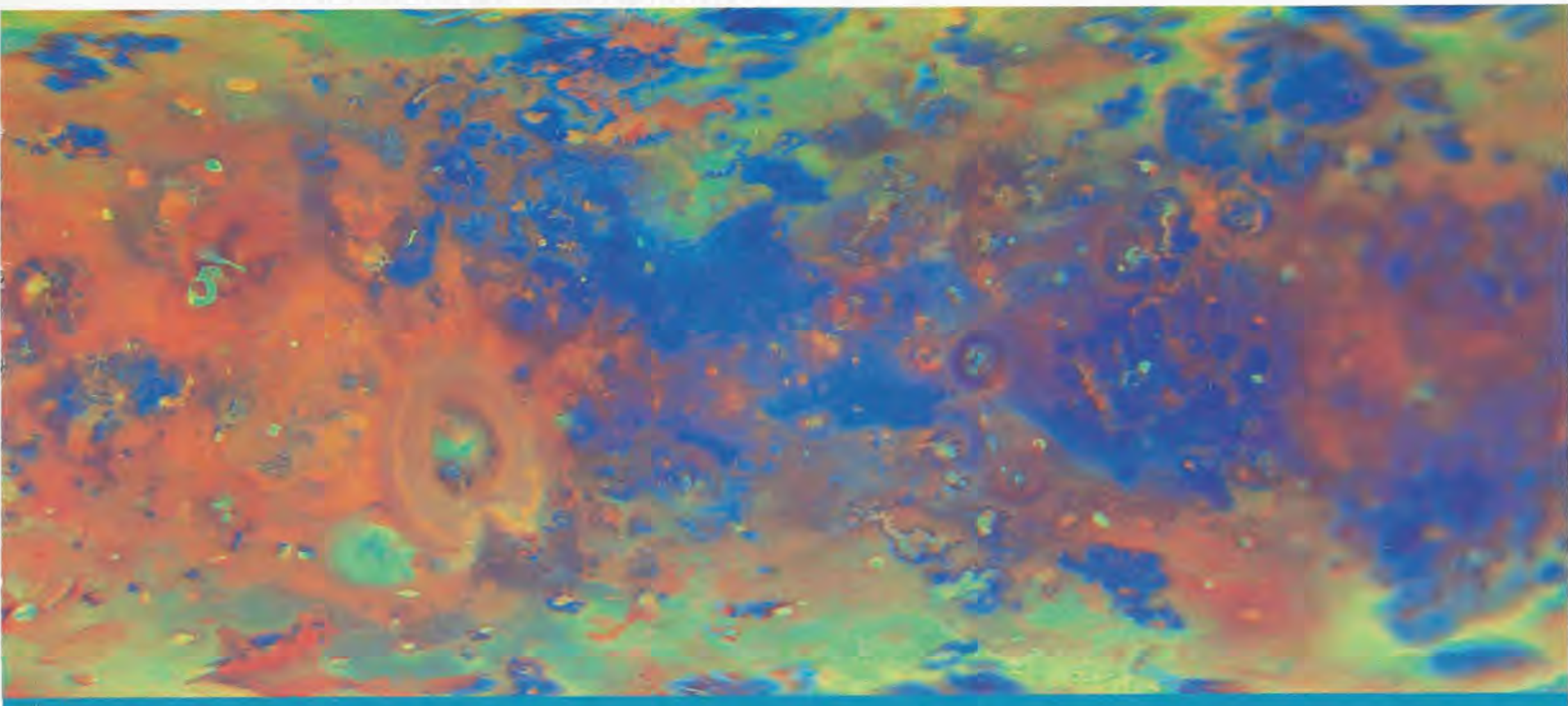
Images of Io accompany this article, the results of new processing of the *Voyager* data performed at the United States Geological Survey in Flagstaff, Arizona. Techniques for analyzing the imaging data continue to improve, and the more scientists study pictures of this intriguing moon, the more they learn about the volcanic processes that continually change its surface.

As *Voyager 1* made its closest approach to Io, it could not image the entire visible surface of the moon with all of the filters on the narrow-angle camera; the spacecraft was simply too close, the fraction viewed in each image too small, the time too short. This camera was programmed to use primarily the clear filter, imaging as much of the surfaces as possible with high resolution (the camera's ability to pick out detail). Meanwhile the lower-resolution wide-angle camera, shuttered simultaneously with the narrow-angle, covered larger areas with all of its filters. During approach and departure, the narrow-angle camera was able to view the planet through the colored filters, but these images had lower resolution than those taken through the clear filter at closest approach.

The information provided by these colored images is important to scientists; with these data they can interpret the chemical and mineralogical compositions of planetary bodies. Colored images are especially important to understanding Io with its great variety of surface materials. We can combine the images produced by the different colored filters to approximate natural color pictures, or we can exaggerate the subtle colors so that different units on the planet can be more easily distinguished. The natural color images are not necessarily what we would see with our eyes; instead, it is the calibrated color balance of the *Voyager* "eyes." In the enhanced color images shown here, white appears as bright blue, gray as dark blue and brown as green, while the reddish and black areas are nearly unchanged. We can further enhance the images by using color ratios, as in our cover image. These are called "false color" because their colors differ vastly from natural colors. The bright white areas in the more normal color images (bright blue in enhanced color) are probably rich in sulfur dioxide (SO_2), while the red, orange, yellow and black *(continued on page 10)*

These global mosaics of Io, constructed from *Voyager 1* images, include the same region as this issue's cover but are simple cylindrical map projections, rather than Mercator projections. We combined data from the orange, blue and violet filters to produce the approximate natural color of the bottom left image. In the false color image below, subtle color variations are emphasized so that things that are red are very, very red and things that are blue are very, very blue. Dark regions have been exaggerated to appear as green. *Voyager 1* detected several hot spots on Io; these spots show up as bright blue-green in this image and represent active or recently active volcanos.

IMAGES: ALFRED McEWEN AND LAURENCE SODERBLOM/U.S.G.S.



ABOVE: The large volcanic structure of Pele, named for the Hawaiian goddess of volcanos, was discovered in an image returned by *Voyager 1.* In this newly processed image, we look down through the plume toward the hills and central valley of Pele ("like looking through a jellyfish," according to Sue Kieffer of the U.S.G.S., an expert on Io's volcanic plumes). The erupting plume here appears above the limb (apparent edge) of Io, rising 300 kilometers above the moon. The geyser-like eruptions have deposited concentric rings around Pele, here running diagonally from upper left to lower right. The outermost ring averages 1,400 kilometers in diameter.

IMAGE: ALFRED McEWEN, TAMMY ROCK AND LAURENCE SODERBLOM/U.S.G.S.

UPPER RIGHT, NEXT PAGE: False color images are not always "psychedelic"—by manipulating colors and contrast, scientists can make certain geologic features stand out from their surroundings. Io's equatorial region is seen here in natural color (left) and enhanced color (right). Dark tendrils of red, brown and black lava, thought to be colored by sulfur, mark the slopes around Ra Patera (lower left of image), some stretching 200 kilometers from the central caldera. The white deposits may be erupted sulfur in a different form or in compounds such as sulfur dioxide. A bluish crescent (center of image) within another caldera may signal a low-energy eruption. IMAGE: ALFRED McEWEN/U.S.G.S.

RIGHT: By combining
Voyager's narrow-an
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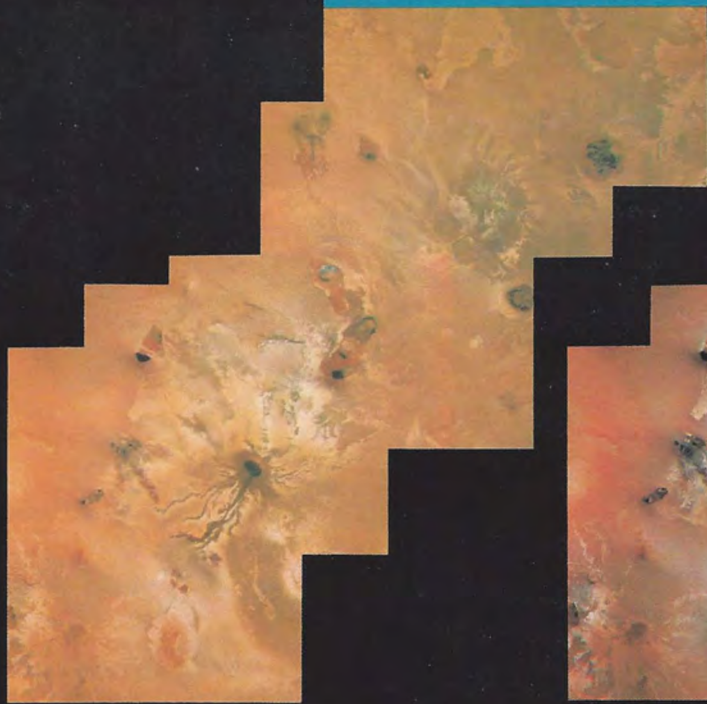
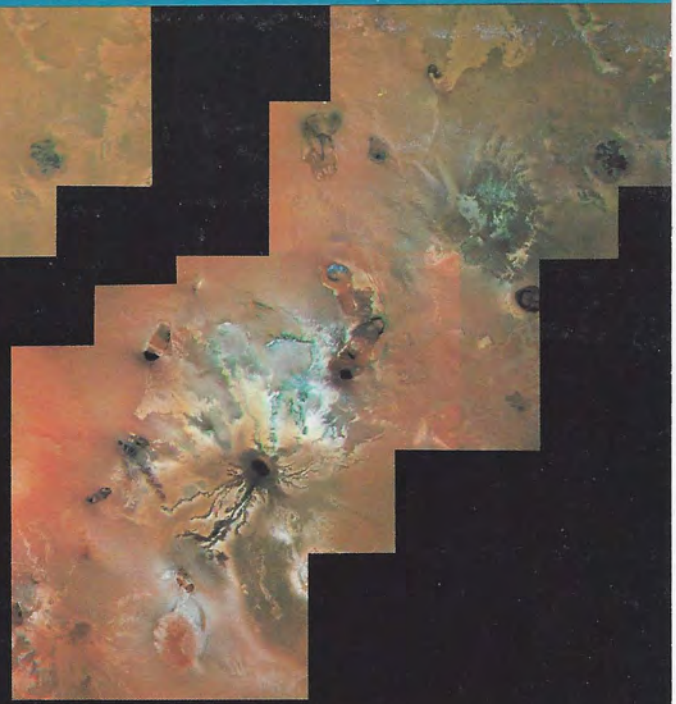
IMAGE: ALFRED McEWEN,





nigh-resolution, clear-filter images from
gle camera with color-filter wide-angle images,
lution-enhanced color images rich in both detail
south pole of Io, where volcanic vents and depos-
paced than in the equatorial region. A large, com-
us Mons (bottom and inset) rises 10 kilometers
me scientists have speculated that sulfur forms
f Io; others believe silicates play some role. Gary
r of the U.S.G.S. have shown that sulfur does not
support a mountain as high as Haemus Mons,
ntains on Io are probably primarily composed of
anets of the inner solar system.

AMMY ROCK AND LAURENCE SODERBLOM/U.S.G.S

(continued from page 7)

areas may represent various other forms of sulfur or sulfur compounds.

The high-resolution, clear-filter images are also very important for geologic interpretations; with the increased detail, we can see the structure and form of mountains, lava flows, faults and rifts. The ideal image, then, for the study of Io's surface would be a combination of the color data with high-resolution images. This is what we have produced in the images displayed on these pages.

With image-processing techniques, images can be multiplied and divided like numbers. High-resolution (high-res) versions of the orange-, blue-, and violet-filter images are created by:

$$\text{high-res orange} = \frac{(\text{high-res clear}) \times (\text{low-res orange})}{(\text{low-res clear})}$$

$$\text{high-res blue} = \frac{(\text{high-res clear}) \times (\text{low-res blue})}{(\text{low-res clear})}$$

$$\text{high-res violet} = \frac{(\text{high-res clear}) \times (\text{low-res violet})}{(\text{low-res clear})}$$

The spectral responses of the high- and low-resolution clear-filter images effectively cancel, leaving the colors, while the spatial frequencies (changes in the pixel-to-pixel brightness) of the two low-resolution images also cancel, leaving the high resolution.

With these images we can make several correlations between color and geomorphology (the structure and form of a planet's surface). Bright white (or bright blue) areas in the enhanced color images tend to contain features formed by tectonic processes (movements of the crust), such as mountains, faults or fractures. This is consistent with the interpretation that the white areas are covered with sulfur-dioxide frost; sulfur dioxide would be a liquid at depths within Io's crust, so it could freely migrate up fractures to the surface and freeze.

Many calderas (volcanic or tectonic depressions) on Io are black and bright orange, a seemingly unlikely combination. But liquid sulfur is very fluid within two temperature ranges—corresponding to its black and orange forms. In these two forms, sulfur may easily extrude through Io's crust, flooding caldera floors.

Although we have learned much about this dynamic moon of Jupiter from the *Voyager* images, we still have many questions about what materials and processes shape the face of Io. Scientists working in laboratories on Earth are helping to answer many of these questions. Jonathan Fink, Seung Park and Ronald Greeley at Arizona State University are experimenting with sulfur lava flows. Jonathan Gradie and others at Cornell University are measuring the reflectance of sulfur and sulfur-silicate mixtures. Douglas Nash and colleagues at the Jet Propulsion Laboratory are studying the low-temperature and low-pressure physics of sulfur dioxide frost and sulfur dioxide and sulfur mixtures. Through such continuing research efforts, we are just beginning to understand this fantastic piece of the solar system.

Alfred McEwen and Laurence Soderblom are geologists with the Branch of Astrogeology, United States Geological Survey.

Loki Patera (lower right) is the largest hot spot on Io. The large, black, horseshoe-shaped feature may be a lake of molten lava. In these images (true color, top; false color, bottom), the Loki plumes are erupting from each end of a 200-kilometer-long fissure above Loki Patera. The plumes have spread bright fans and darker deposits around the black fissure.

IMAGE: ALFRED McEWEN, TAMMY ROCK AND LAURENCE SODERBLOM/U.S.G.S.

by Clark R. Chapman

This year will see much public discussion about our country's goals in space and about how NASA will meet those goals. The space station has been proposed as the next major initiative for the US space program. But it is unclear if NASA is prepared to embark on a big new project without running roughshod over its existing, unfinished endeavors. Since the Space Shuttle project began in the early 1970's, NASA has had a problem in nurturing small programs while trying to bring a large project to successful completion within budget. In recent weeks I have been reading and learning about NASA's space station plans as well as about a small but beautiful project called IRAS, which is at the opposite end of the cost spectrum.

Amazing IRAS

Last winter I watched from my home in Arizona as IRAS, the Infrared Astronomical Satellite, was launched into orbit hundreds of miles to the west. The spectacular light show in the western sky marked the start of a largely unheralded but wonderfully successful satellite mission. At the end of November, 1983, the infrared "eyes" of IRAS finally went dead as the telescope's liquid helium coolant supply was exhausted. But in the course of mapping the heavens in the wavelengths obscured by our atmosphere, IRAS has changed our views about the solar system, our galaxy and the universe. IRAS is a small project by NASA standards; its total cost, spread over many years, is only a few percent of NASA's annual budget. (In this case, some of the costs were borne by the Netherlands and Great Britain, our partners in this international scientific endeavor.) Despite its modest cost, IRAS has made fundamental contributions to our knowledge of our place in the universe.

Last summer, IRAS made the front pages when its team of scientists announced the discovery of a possible planetary system around Vega, the nearby star that gleams overhead on a summer evening. It is not really known what kind of objects are in orbit around Vega—IRAS may have observed a gigantic asteroid belt or a swarm of objects arrested in the process of forming a planetary system—but the discovery has profound implications for the abundance of planetary abodes for life in the universe. In retrospect, it is not surprising that IRAS should have had such relevance for us. The universe of optical astronomy, after all, is filled with the hot, glowing objects called stars, while life is nurtured on the cold bits of flotsam and jetsam called planets. Planets, comets, molecular clouds and the other cold materials in the universe are all too cold to glow at visible wavelengths, but they do shine in the infrared—just the wavelengths to which IRAS's detectors were tuned. So IRAS provided us with a window to the cold parts of the universe, of which we ourselves are part.

Space Station

As I flew to Jet Propulsion Laboratory for an IRAS briefing a few days after IRAS died, I read Brian O'Leary's short, timely book, *Project Space Station* (Stackpole Books, 1983). The space station is a project on a different scale from IRAS—we could do dozens and dozens of IRAS projects for the projected cost of the space station. But then Brian O'Leary, and most space enthusiasts, have very high hopes for what a space station can mean. Anyone who was entranced by the wheeling space station in Stanley Kubrick's "2001: A Space Odyssey" can hardly doubt that a space station will be a part of our future enterprises of space exploration. The problem that besets O'Leary is that while he *believes* that wondrous things will flow from a space station, he is hard-pressed to predict the specific benefits of the project that will justify the costs to a hard-nosed Office of Management and Budget that guards the overtaxed citizens' pocketbooks.

In *Project Space Station*, O'Leary tries to list the scientific, commercial and military applications that can be met in a cost-effective way by a space station. Quite frankly, the arguments ring hollow and one can tell that the author's heart lies elsewhere. Toward the end of the book, O'Leary provides another list of what really turns him on: tourists traveling to hotels in Earth orbit, mining the asteroids for precious metals, colonizing space and so on. What do such grandiose dreams of the future have to do with the comparatively modest space station NASA wants to build? O'Leary is not very specific, but it is easy to feel, as he does, that NASA should adopt a more visionary perspective towards its role and that a space station is a plausible first step to more expansive endeavors. O'Leary realizes that he is a dreamer and his book reflects his frustration at having to justify his dream to the bean-counters that stand in the way of humankind's conquest of space.

And Caveats

However, the new arguments of O'Leary about the cost/benefit ratio of commercial space operations with a space station sound like the overly-optimistic predictions of a Shuttle-launch-per-week by the early 1980's that we heard a decade ago when NASA was trying to line up support for that big new project. As O'Leary describes in his book, he was one of the more vocal opponents of the Shuttle then. His early-1970's prediction that Shuttle economics would squeeze out space science and other NASA endeavors proved prophetically accurate. Now O'Leary believes the space station will "pull us into the future" and asks that we suspend any skepticism.

Many will be looking to see if President Reagan's fiscal year 1985 budget proposals will illustrate whether the Executive Branch is prepared to uphold NASA's commitment to explore the solar system in ways other than just by building big things. For example, take the planetary program, which nearly died two years ago. Will the research and analysis programs be returned to their fiscal year 1981 levels, as NASA promised? Will there be a new start for the Mars Geochemistry/Climatology Orbiter, the first of the series of Planetary Observers recommended by the Solar System Exploration Committee? Will NASA augment the meager data analysis programs now planned to meet the promise of the IRAS data? If NASA shows that it cares about all its programs, most skeptics in the space community will applaud its bolder approach to the future.

Clark Chapman is a research scientist at the Planetary Science Institute, a division of Science Applications, Inc.

World

by Louis D.

Last October, as a guest of the Institute for Space Research, USSR Academy of Sciences, I visited two of their leading space science centers. My tour included the Institute image processing laboratory, the Vernadsky Institute for Geochemistry and Analytical Chemistry, the lunar rocks and meteorite receiving laboratory, and the testing and development facilities for VEGA, the 1984–86 mission to Venus and Halley's Comet (VEGA is the acronym for VEnera-GAlley, the Russian names for Venus and Halley). Looking down at the test model of the spacecraft, I was struck by the scope of the mission—and the openness of the Soviet scientists sharing their plans for it. VEGA is really three missions in one: a balloon flight near Venus' clouds to measure atmospheric properties, a night landing on Venus to study geochemistry, and a survey of Halley's Comet.

My hosts for the look at the VEGA spacecraft and testing areas, Society Advisor Roald Sagdeev and Simon Lubman, the chief engineer for the project, repeatedly emphasized the mission's complexity. Scientists of five nations, working on their instruments, were clearly anxious—hardware delivery for the scientific instruments was only a month away. (The launch is set for December, 1984.) The imaging experiment is truly international; I watched the Czechoslovakians testing their scan platform, the Hungarians their optics, the Russians the CCD array (a new solid-state charge-coupled-device sensor), the French their telescope and the Poles their software.

However, the purpose of the trip was not sightseeing; it was to explore ways for The Planetary Society to operate in the Soviet Union. The Society's purpose there is the same as it is elsewhere: to encourage continued exploration of the solar system and the search for extraterrestrial life by providing a focus for popular interest in these subjects. Academician Roald Sagdeev was particularly helpful in setting up meetings with editors of two large magazines and in arranging for consideration of televising material from *The Planetary Report* in the USSR. He is also looking at other magazines and other mass media arrangements for distribution of the *Report.* I also met with Soviet planetary scientists to discuss the *Venera,* VEGA and other future missions, and the search for extraterrestrial life.

Soviet planetary scientists seemed to have high regard for The Planetary Society, to share similar goals, and to appreciate the international exchange of public information afforded by *The Planetary Report.* They often gave high praise for the magazine. The September/October 1983 issue included new versions of pictures of the Venus surface taken by *Veneras 13* and *14,* processed by Brown University scientists, which were so new that the Soviets had not yet seen them. They, in turn, provided me with new pictures and data from *Veneras 13* and *14.*

We also discussed how the Society could promote international cooperation on space missions. Some specific suggestions were made as a result of their plans for new missions [*see box*]. Scientists and mission planners from the US, Europe and Japan have also expressed support for the Society to organize meetings and promote activities that will stimulate new international space exploration programs. This would fulfill two of our primary goals: to serve a global constituency, and to encourage continued and revitalized exploration of the solar system.

Following my visit to the Soviet Union, I met with the Hungarian Astronautical Society, our liaison organization in Hungary, at the International Astronautical Federation (IAF) meeting in Budapest. They expressed their appreciation for the regular distribution of *The Planetary Report* in their country. The Hungarians are actively interested in space exploration and have played a major role in the VEGA mission. I also met with representatives of space organizations from Great Britain, France, China, Poland and Germany.

The technical sessions of the IAF showed the diversity of space interest throughout the world. The symposiums on SETI were characterized by general speculation about extraterrestrial intelligence, rather than by hard data. Dr. Michael Papagiannis, President of the International Astronomical Union's SETI Commission, noted that we are in the position of the ancient Greeks with regard to astronomy: We have little data, but lots of philosophy and theory. The Society's Project Sentinel and its support for SETI observations at the NASA Tidbinbilla station in Australia were noted as the major search programs now underway and collecting data. The SETI symposium included papers by scientists from the US, USSR, Czechoslovakia, Poland, Hungary and England. J. B. Corliss of Oregon State University described the detection of life near seafloor hot springs, and suggested that the energy in such hot springs might have been the source for the origin of life on Earth.

This test model of the Soviet's VEGA spacecraft is used to check out science instruments. VEGA will be launched to Venus and Halley's Comet in December, 1984.

Louis Friedman (left), Planetary Society Executive Director, examines equipment used to test the VEGA spacecraft model with a staff member of the Institute for Space Research.

PHOTOS COURTESY THE INSTITUTE FOR SPACE RESEARCH

Watch

Friedman

International cooperation was a topic at three sessions on solar system exploration. Hungarian and French scientists described their work on the VEGA project. Richard Spehalski of the Jet Propulsion Laboratory discussed the Federal Republic of Germany's contribution of the retropropulsion module for Project *Galileo*. Peter Lyman of JPL presented a proposal for international cooperation on tracking and data acquisition for deep space missions.

Astronauts and cosmonauts from the US, Soviet Union, Eastern Europe and France also attended the IAF; Sally Ride and Svetlana Savitskaya caught most of the attention. US space officials discussed space station planning. In one remarkable talk Konstantin P. Feoktistov, a Soviet cosmonaut who flew on *Voskhod 1* in 1964, stated that "there is nothing that man can do in space that couldn't be done better and easier by machine." This comment did not dampen the interest at the meeting in the astronauts' activities in space.

In Budapest, I visited the major planetarium and exchanged educational material on space flight with the director. Planetariums in Eastern Europe, as elsewhere, have a major role as a resource for students. We talked about the need for better, more current educational material for teaching the new knowledge gained from our exploration of the solar system. Exhibits in both the Moscow and Budapest planetariums included many NASA and JPL photos, as well as, of course, *Venera* and *Salyut/Soyuz* photos.

The third stop on my trip was the International Halley Watch (IHW) meeting in Bamberg, Germany. I was invited to be a member of the NASA–IHW Steering Group. The IHW will coordinate observations of Halley's Comet around the world and in space, enabling both new data analysis and synthesis. Currently some 700 scientists from 43 countries are participating in six major scientific disciplines. In addition, the IHW is serving as a liaison between amateur astronomers and professionals, for it is expected that data from amateurs will add significantly to the science that will be learned from this apparition.

The Planetary Society will follow closely the progress of the several Halley space missions, monitor the results of the IHW efforts, and report that information to you in *The Planetary Report*. We also have agreed to take over distribution of the IHW Amateur Observers Bulletin for NASA.

The Planetary Society now has members in 60 other countries, and official representatives in 7; we are establishing several formal relationships for the worldwide distribution of *The Planetary Report*. This trip emphasized to me that, despite the many difficulties between countries with different languages, as well as different social, economic and political structures, the role we seek—to be the global focus for popular interest in the exploration of the solar system—is worth striving for. And, possibly, success in serving that role may reach far beyond the space program or scientific interests of nations.

Cooperation for Halley

The Soviet Union recently agreed to cooperate with NASA, the European Space Agency (ESA) and Japan to improve the results from all spacecraft that will observe Halley's Comet on its return to the inner solar system in 1986. Intercosmos, a Soviet-led consortium of Eastern European nations, is sending two VEGA spacecraft to Venus and then on to Halley's Comet. They will provide imaging data that will help the Europeans target their *Giotto* spacecraft during its encounter with the comet. NASA is not sending a spacecraft, but they will provide the Soviets and the Europeans with ephemerides (position predictions) and tracking data from the Deep Space Network of antennas. The Soviets will also provide information to the Japanese, who are planning to launch two spacecraft in the direction of Halley's Comet. The NASA, ESA and Intercosmos cooperation on the Halley Comet missions was described in the April/May 1981 issue of *The Planetary Report*.

In Our Next Issue

In late January, President Reagan will submit the fiscal year 1985 budget to Congress. In our next issue, we will report on the budget proposal and the ensuing congressional deliberations on possible new initiatives for a space station and other space programs. Members who would like a copy of the proposed NASA budget for FY '85 should send a self-addressed stamped business envelope to: The Planetary Society, Budget, P.O. Box 91687, Pasadena, CA 91109.

Louis Friedman is Executive Director of The Planetary Society.

Possible Soviet Planetary Missions

One of the major subjects of my trip was future missions. I presented a lecture on US planning to scientists at the Soviet Union's Institute for Space Research, describing the recent work of the Solar System Exploration Committee. The Soviets, in turn, discussed some of their advanced studies. It is important to note that these missions are under *study*, not yet approved.

Mars Orbiter/Phobos Rendezvous—The primary goal of the next Mars mission by the USSR, to be launched in 1988 or 1990, appears to be a close rendezvous with the satellite Phobos. Because of the physical similarity of Phobos to a "typical" asteroid, the Soviet scientists frequently refer to their Phobos mission as an asteroid rendezvous. They are studying ways to measure surface composition from close rendezvous. Phobos has always been an object of interest to the Soviets—some of you may remember the well-publicized hypothesis offered by one scientist prior to the *Mariner 9* mission, that Phobos might be a hollow artificial satellite. Since NASA is planning its first Planetary Observer—the Mars Geoscience Climatology Orbiter—for the same time period, but with different objectives, complementary planning was suggested.

Lunar Polar Orbiter—This mission, often discussed in the US, the European Space Agency and Japan, is apparently being seriously considered for a launch by the Soviet Union between 1989 and 1992. They are examining international involvement, maybe with Western European nations. The mission would provide a geochemical map of the Moon by remote sensing and search for possible locations of lunar water.

Advanced Venus Missions—Several new generation *Venera* missions are under study. French scientists are involved in planning a large balloon mission which appears to be scheduled for 1988. Longer-lived landers are also under study, although different ideas such as "hoppers"—vehicles that can land and take off—are also being investigated. Dr. L. V. Ksanfomality, a scientist at the Institute for Space Research, showed me some interesting data concerning soil movement and volcanos on Venus, and emphasized the desirability (and difficulty!) of including seismometers on future Venus landers.

Radio Telescope—The Soviets continue design work on a large space radio telescope for radio astronomy. Best estimates are that launch is still five years away. Such a telescope would be used for SETI observations, although that would not be its principal function. Soviet interest in SETI is high (see the May/June 1982 issue of *The Planetary Report*) although the actual number of observation programs remains low.

SOCIETY NOTES

MARS INSTITUTE CONTEST

The Planetary Society's Mars Institute, which is exploring the possibility of human activity on Mars, is holding a student contest for the design of a Martian base water supply system. The contest is open to any high school or college student. The winner will receive a one-week, all-expense-paid trip to the annual Mars Institute conference to present his or her paper. For more information, please write to: **Mars Institute Contest, The Planetary Society, 110 South Euclid Ave., Pasadena, CA 91101.** The Society has sent booklets describing the Mars Institute to university faculties around the world who are interested in giving courses concerning the further exploration on Mars leading to human activity on the red planet. We hope that the first courses will begin this year. The first Institute conference is planned for July in Boulder, Colorado.

THE MEDIA AND META

The news media extensively covered our October announcement of Project META, the expansion of Project Sentinel at Harvard University's Oak Ridge Observatory (see page 3). Professor Paul Horowitz and his project appeared on network news programs, local television and radio shows, and in many newspapers. We were particularly pleased that the Cable News Network broadcast part of our multimedia show, "Exploring Other Worlds."

SEARCHING FOR ANALOGS

The Society is holding a symposium, "Searching for Our Analogs in the Universe," in New York City on May 27, 1984 (during Memorial Day weekend). Five speakers will address various aspects of this topic, and continue a program on analogs begun last year at the annual meeting of the American Association for the Advancement of Science. The AAAS's annual convention is being held this year in New York, May 24–29, and we will have an exhibit at their meeting. We will announce details of the symposium on our information lines some time in February. *Planetary Society Information Lines: From east of the Mississippi, call (213) 793-4328; from west of the Mississippi, call (213) 793-4294.*

SEDS SYMPOSIUM AND DINNER

The Students for the Exploration and Development of Space (SEDS) are having their Fourth Annual Space Symposium on February 25 and 26, from 1–4 pm each day, at the Gallagher Theatre at the University of Arizona, Tucson. On the evening of the 25th, the Federation of Aerospace Societies of Tucson (FAST), in conjunction with The Planetary Society, is hosting a buffet dinner at the Flandrau Planetarium in Tucson. Dr. Thomas R. McDonough, SETI Coordinator for the Society, will be the featured speaker. Costs are $15.00 per person or $25.00 per couple. If you would like to attend, please send a check or money order made out to FAST to the Planetarium by February 15, 1984. For more information, call or write: **Flandrau Planetarium, University Blvd. and Cherry Ave., University of Arizona, Tucson, AZ 85720, Attn: Loni Baker, 602/621-4515.**

COOPERATION IN SPACE

Louis Friedman, Executive Director of The Planetary Society, spoke on "International Cooperation in Space Exploration" (see pages 12 and 13) to over 200 members at the Pasadena Center in November. Before the lecture, the Society hosted an open house for members at our offices.

NEW EDUCATION PROGRAM

The Planetary Society is now working on a planetary science education program aimed at junior high school teachers. We will be developing materials to help teachers encourage students to excellence in all types of academic endeavors, including the sciences. If practical, we would like to work with our members in developing this program. If you have professional experience in teaching junior high students and have ideas on how the Society could help, please write: **Charlene Anderson, The Planetary Society, 110 S. Euclid Ave., Pasadena, CA 91101.**

AUDIT COMPLETED

The Price Waterhouse audit of our complete 1983 financial statement resulted in an opinion with no qualifications, finding our statements in conformity with generally accepted accounting principles. A one-page summary is available upon request.

CASE FOR MARS II

Human exploration of Mars will be the topic of The Case for Mars II, a conference to be held in Boulder, Colorado from July 10–14, 1984. Sponsored by The Mars Institute of The Planetary Society, the Boulder Center for Science and Policy and the University of Colorado Space Interest Group, the conference will bring together people who are actively working toward these goals. The meetings are open to students, faculty and other scientists and engineers who are doing research on Mars. If you would like more information on the conference write: **Carol Stoker or Tom Meyer, Case for Mars, P.O. 4877, Boulder, CO 80306.**

SOCIETY IN THE NEWS

Newpapers, magazines and other publications around the country frequently carry stories that mention The Planetary Society and our activities. But unless members send them to us, we rarely see them. We would like to start collecting these articles for our permanent files. We would appreciate it if interested members would clip out the articles, note the date and name of the publication and send them to: **Newsclips, P.O. Box 160, Bronx, NY 10475.**

VISIONS OF OTHER WORLDS

"Visions of Other Worlds," an exhibition featuring the work of artists affiliated with the International Association of Astronomical Artists (IAAA), will premier on February 1, 1984 at the Reuben H. Fleet Space Theater in San Diego. The exhibition, consisting of 100 pieces by 24 artists, may be the largest of its kind in history. After leaving San Diego on March 15, "Visions of Other Worlds" will travel to the Flandrau Planetarium in Tucson, Arizona.

LIFE IN THE UNIVERSE

Stanford Medical Center will be the site of a lecture course "Life in the Universe," to be held on March 3 and 4, 1984. The program was developed by Dr. John Billingham, Chief of the Extraterrestrial Research Division of NASA-Ames Research Center, and Dr. Edward Rubenstein, Associate Dean of Postgraduate Medical Education of Stanford University School of Medicine. Cost for Planetary Society members will be $125, a fifty percent discount. For further information, contact: **Martha P. Amlin, Stanford University School of Medicine, Office of Postgraduate Medical Education, Room TC 129, Stanford, CA 94305.**

The Solar System in Pictures and Books

● BOOKS	PRICE	QUAN	TOTAL
Voyages to Saturn by David Morrison – Description of both Voyager Saturn encounters, with color photographs.	$14.00		
Voyage to Jupiter by David Morrison and Jane Samz – Description of both Voyager Jupiter encounters, with color photographs. 199 pages.	$10.00		
The Grand Tour: A Traveler's Guide to the Solar System by Ron Miller and William K. Hartmann – A beautifully illustrated guide to 25 worlds in our solar system. 192 pages.	$ 9.00		
The Surface of Mars by Michael H. Carr – A definitive summary of Viking mission results. Large format. 232 pages.	$32.00		
Planets of Rock and Ice by Clark R. Chapman – Guide to the small planets from Mercury to the moons of Saturn.	$10.00		
The New Solar System edited by J. Kelly Beatty, Brian O'Leary and Andrew Chaikin – Up-to-date information on our planetary neighborhood. 224 pages. **Hard cover–1st Ed.** / **Soft cover–2nd Ed.**	$8.50 / $9.50		
The Moon by Patrick Moore – An atlas and guide to our satellite. 96 pages.	$11.00		
Jupiter by Garry Hunt and Patrick Moore – A well-illustrated look at the largest planet in our solar system. 96 pages.	$11.00		
The Voyager Flights to Jupiter and Saturn—The official summary of the Voyager encounters. 64 pages.	$ 6.50		
Murmurs of Earth by Carl Sagan, Frank Drake, Ann Druyan, Timothy Ferris, Jon Lomberg and Linda Salzman Sagan – Account of the development of the Voyager record, a message from humanity to possible extraterrestrial life forms. 273 pages.	$ 7.00		
The Planets edited by Bruce Murray —Collected articles from Scientific American, presenting the state-of-the-art in planetary science. **Soft cover** / **Hard cover**	$ 8.50 / $14.50		
A Meeting with the Universe edited by Bevan M. French and Stephen P. Maran – Everything from the origin of the Sun to the edge of the universe is covered in this well-illustrated volume. 221 pages.	$14.00		
Distant Encounters by Mark Washburn – The excitement of the Voyager encounters is captured for those who could not be part of the events. 272 pages.	$10.00		
Out of the Darkness by Clyde W. Tombaugh and Patrick Moore – The discovery of Pluto is chronicled by its discoverer and a noted science writer. 221 pages.	$13.00		
Mission to Mars by James E. Oberg – Plans and concepts for the first human mission to Mars are detailed in this up-to-date book. 221 pages.	$13.00		
Planetary Exploration Through Year 2000—This colorfully illustrated executive summary of the Solar System Exploration Committee details the proposed future of planetary exploration. 30 pages.	$5.50		
Earth Watch by Charles Sheffield—A magnificent view of the Earth from Landsat in full-color and large format. 160 pages.	$20.00		
Pioneer Venus by Richard O. Fimmel, Lawrence Colin and Eric Burgess—A readable account of the Pioneer mission to Venus, illustrated with color photos and paintings of the veiled planet. 253 pages.	$11.00		
New Earths by James Edward Oberg—The possibility of turning other planets into new Earths is explored in this illustrated volume. 283 pages.	$5.50		

Back issues of THE PLANETARY REPORT are now available to Society members. Each volume contains six issues. (Volume I, Number 6; Volume II, Numbers 1, 5 and 6; and Volume III, Number 1 have been sold out.) Specify the issues you would like by volume and number. A donation of $1.50 per issue to cover printing and postage costs is appreciated.

Total quantity of back issues ____________ Total price ________

Mars in 3-D—This 16mm film, produced by Elliott Levinthal, depicts the Martian landscape as seen by Viking. It may be purchased for $125.00 or rented for $25.00, with a deposit of $100.00. 3-D glasses are available for $.25 each. Write to The Planetary Society for a rental agreement or purchase information.

● COLOR PHOTO REPRODUCTIONS (8½" x 11")	PRICE	QUAN	TOTAL
Jupiter – A montage of the planet and its Galilean Moons, the Great Red Spot and dynamic Io. (set of 3 prints)	$ 2.00		
Mars – Approaching the red planet, Martian sunrise and sunset, the rocky surface at both Viking landing sites (set of 4 prints)	$ 3.75		
The Best of Voyagers 1 & 2 at Saturn – The planet, its rings and satellites (set of 15 prints)	$10.00		
Voyager 2's Future Missions – Don Davis paintings of the encounters with Uranus and Neptune (set of 2 prints)	$ 2.00		

● LASER COLOR PRINT (16" x 20")	PRICE	QUAN	TOTAL
Apollo Photograph of Earth (full disk)	$ 8.00		

● COLOR POSTERS	PRICE	QUAN	TOTAL
Voyager at Jupiter (Six 23" x 35" posters)	$16.00		
Voyager 1 at Saturn (Five 23" x 35" posters)	$16.00		
You Are Here (23" x 29" poster)	$ 5.00		

● 35MM SLIDE SETS	PRICE	QUAN	TOTAL
Voyager 1 Saturn Encounter (40 slides with sound cassette)	$15.00		
Voyager 2 Saturn Encounter (40 slides with sound cassette)	$15.00		
Viking 1 & 2 at Mars (40 slides with sound cassette)	$15.00		
Voyager 1 & 2 at Jupiter (40 slides with sound cassette)	$15.00		
The Solar System Close-Up, Part One (50 slides with booklet)	$36.00		
The Solar System Close-Up, Part Two (50 slides with booklet)	$36.00		

● SALE ITEMS	PRICE	QUAN	TOTAL
The Planets: A Cosmic Pastoral by Diane Ackerman—A collection of poems about the planets. 159 pages.	$ 2.00		
Planetfest '81 Posters (Two 23" x 35") of Saturn and the F-ring	$ 6.00		
Space 1984—Full color calendar	$ 3.50		

Mail order and payment to:

THE PLANETARY SOCIETY
P.O. Box 91327
Pasadena, CA 91109

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Officers of The Planetary Society do not receive any proceeds from sales of books of which they are authors and contributors.

STARFLOWERS—In this metaphorical painting of star formation, Jon Lomberg depicts glowing nebulae as flowers producing young stars and scattering them like seeds through space. Eventually, these young stars will age and die, returning their gas to space to produce new "starflowers." Our own solar system had its origin inside one of these gas clouds.

Jon Lomberg is an artist who has worked with The Planetary Society and Carl Sagan on many projects. He designed the Society's logo and recently produced "Exploring Other Worlds," the Society's multi-media show. He lives in Toronto, Ontario.

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