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COVER: Photographing Saturn's rings is only one way to study them. This image was generated by a computer using data gathered by* Voyager 2*'s photopolarimeter while the rings occulted the star Delta Scorpii on August 25, 1981. The rings appear brightest where they are most opaque. The insert shows the F-ring with a resolution of one kilometer. This experiment, and the radio occultation experiment (pages 4-7), revealed details of the rings invisible to the spacecraft's cameras.
Image: Larry Esposito, University of Colorado, Boulder

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, The Planetary Society, 65 N. Catalina Ave., Pasadena, CA 91106.

I am an avid reader of your *Planetary Report* and have been a member of The Planetary Society since its inception. In the March/April issue you printed an article called "Visions of 2010." I don't suppose you could move the timetable up five years. I expect to live until 2005, when I will be 100 years old and would enjoy reading about human missions to Mars, the Moon and the asteroids!

WILLIAM R. ROYAL, *Warm Mineral Springs, Florida*

The symposium on weapons in space (May/June 1985 *Planetary Report*) clearly revealed how sharply divided opinions can become. Dr. Cooper's insistence that we shall carry warfare into space, along with the more positive things we've learned on Earth, sounds like a smoker's complaint that he "just can't quit." The organized destruction of life and property is a bad habit, and a "kickable" one.

The vicious cycle is best broken now. Having a Strategic Defense Initiative is no substitute for the lack of an attack. Cooperation costs relatively little, and friendship costs nothing. A good international relationship between the United States and the Soviet Union constitutes the best possible national defense for all concerned.

DAVID W. SIMS, *Fairborn, Ohio*

Do we need the Strategic Defense Initiative? Ever since humans began killing humans, each new weapon was countered by some form of defense. For the sword, the shield; for gas, a mask; for the heat-seeker, the decoy. Will we sit here in the face of mutually assured destruction and wring our hands and say there is nothing we can do? No. And anyone who says space is sacrosanct is not thinking.

What is space anyway? Man has barely cleared the mantle of Earth's own dust, but look out, future! Space, like every other new frontier, is an extension of man's *lebensraum* and where man goes, he will take his fears and hates and weapons.

DON W. VOGEL, *Brandon, Vermont*

I would like to see more cooperation between the developed and the developing nations. Even a symbolic nut-and-bolt on an interplanetary research project might motivate nations to industrialize in a direction different from militarization. In the case of Brazil, both military and civilian elements are present in the space program. Nevertheless, international cooperation plays a major role in space development.

The emphasis of Brazilian cooperation with other nations has been directed toward research. This includes participation in the Soviet *Vega* mission to Venus and Halley's Comet. The radio telescope at Itapetininga will be part of the coordinated program to navigate *Vega*.

The Brazilian space program, with the launch of the first satellite planned for 1989, is bringing cooperation with the People's Republic of China. The agreements include the exchange of information, science, technology, personnel, and possible mutual use of facilities. The Brazilian-Chinese case is, perhaps, the best example that nations with diverse historical, cultural and political backgrounds can cooperate in the great human adventure.

REGIS CABRAL, *Palatine, Illinois*

Questions & Answers

Perhaps you grew up with telescopic photographs of Mars and you wondered, with Percival Lowell, if the dark lines smudged across its surface were vegetation along canals. And maybe you speculated that the vegetation followed a seasonal cycle, explaining Mars' changing appearance. If so, when the first images came in from Mars-orbiting spacecraft, and revealed no great canals or verdant fields, did you wonder what the dark markings really were?

Sometimes, late at night, pondering your latest issue of *The Planetary Report* and reveling in your new mastery of orbital dynamics, are you ever stumped by a simple-seeming question such as, "Why are planets round?" Do you consider asking your 10-year-old, scientific-whiz child, but don't for fear of looking dumb?

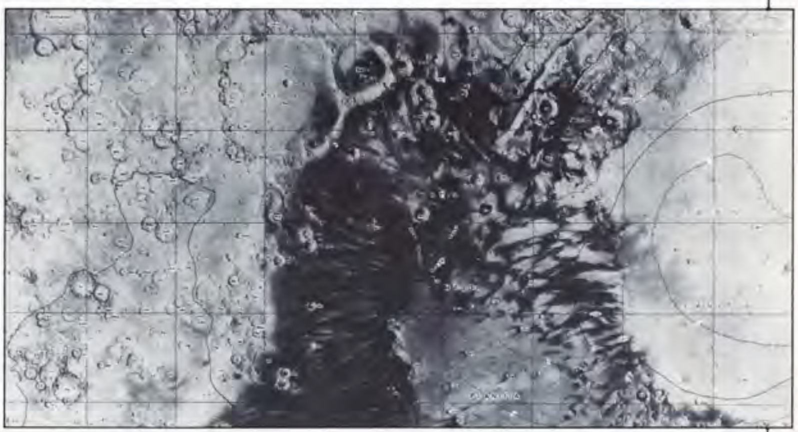
If you answered "Yes" to any of the above questions, then this column is for you. The Planetary Society has access to many of the best practitioners of planetary science, so why not take advantage of your membership, and ask your questions? Keep the questions short and not too technical and send them to: Q & A, The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

***What are Syrtis Major and the other dark markings on Mars?* — Frank Bruguiere, Reston, VA**

Syrtis Major is a vast, flat plain, sloping down toward a basin called Isidis Planitia. The temperature is warmer in the basin. This generates a wind that sweeps across Syrtis Major, stripping off the light-colored dust and exposing the dark lava plain beneath.

As with similar features on Earth, these martian lava flows are believed to be made of basalt, a very dark, fine-grained volcanic rock. A rusty-colored dust covers most of Mars, giving the Red Planet its distinctive color. But underneath this dust often lie ancient lava flows. If they are exposed by the wind — which can blow up into planet-engulfing storms — these basaltic regions appear as dark markings on Mars.

— STEVE WALL, *Jet Propulsion Laboratory*



***Why are planets round?* — L.L. White, Midwest City, OK**

Planets are held together by gravity, the force that pulls all masses in the universe toward each other. This force is balanced in a planet by the increase of pressure within the rock toward the planet's center. If these forces are not balanced in the planet, matter moves around until they are balanced. In an isolated, stationary planet the forces would balance as the matter became spherically symmetrical, that is, round. But if the planet is rotating, or acted upon by the gravity of the Sun or another planet, the only way these forces can be in balance is for the planet to be slightly out of round. Also, convection caused by internal heat sources can disturb the balance slightly.

Thus, planets aren't perfectly round. In planets the size of small asteroids, molecular forces are as important as gravity and pressure changes, and such objects can be quite lumpy. Large planets, such as Jupiter and Saturn, rotate rapidly, so that centrifugal force affects the balance between gravity and pressure changes. These bodies bulge outward at their equators.

— BILL HUBBARD, *University of Arizona.*

TAKING THE MEASURE OF SATURN'S RINGS

by Len Tyler and Dick Simpson

Planetary rings have puzzled astronomers since Galileo turned his first telescope toward Saturn. His notes show that he had seen Saturn accompanied by "two close moons." The moons, however, were not moons at all, but the *ansae*, or apparent "handles" of Saturn's rings, seen at low resolution. Galileo's fundamental question about the objects near Saturn — "What are they?" — has long since been answered. We know they are composed of trillions of orbiting snowballs. Today's questions about the rings center on processes within ring systems — "How do they behave?" — but the answers are no less elusive.

Ring systems are relatively new to our experience and, as we are slowly learning, are very complex. Few laboratory experiments provide insight into ring behavior, nor are rings easily modeled on computers. But thanks in part to occultation experiments carried out during the *Voyager* encounters with Saturn, we are now beginning to understand how these unusual systems work.

Occulting Bodies

The term "occultation" refers to the hiding of one body by another. In the lunar occultation of a star, for example, the Moon passes between Earth and the star. Astronomers have watched stellar occultations by planets for years, primarily to refine ephemerides (computed positions) and determine the shape of the occulting body. The rings of Uranus were discovered in 1977 as the serendipitous byproduct of such observations.

The key to success in stellar occultations is the brightness of a star, a very compact source of light. When we see the edge of a solid body pass in front of a star, the pinpoint is quickly extinguished. Knowing when the light blinked out, we can accurately determine the edge. A set of such observations made by widely spaced observers can provide a silhouette of the occulting body (see the July/August 1984 *Planetary Report*).

If the light intensity decreases gradually, then we know that the occulting limb, or edge, is not sharp — indicating the presence of an atmosphere. Comparing the decrease of a star's intensity with predictions based on theory tells us about the atmospheres surrounding other bodies.

Resolving Details

During their Saturn encounters, *Voyagers 1* and *2* made many occultation measurements of both the planet's atmosphere and its ring system. These measurements have given us very accurate profiles of the rings' opacity, which we can relate to the amount of material present. We have resolved details as fine as a few tens of meters with absolute position accuracy of a few kilometers. No other experiments can approach this precision. These *Voyager* observations have given us new insight on the dynamics of the entire ring system.

***Voyager* stellar occultations were observed primarily with a small, sensitive on-board telescope — the photopolarimeter — which measured the intensity of visible starlight passing through the rings. The photopolarimeter was able to resolve details about 100 to 1000 meters across. Other *Voyager* instruments, operating in the infrared and ultraviolet, were also used, but they were less sensitive than the photopolarimeter.**

***Voyager 1* also conducted radio occultation experiments. Microwave signals from the spacecraft's transmitters were beamed through the rings and received an hour and twenty-five minutes later at NASA's Deep Space Network tracking station near Madrid.**

Because we accurately controlled *Voyager's* radio signals, we could attribute even small perturbations of the signals to interactions with the rings. Data from stellar occultations cannot be analyzed with such detail because the star's emissions are random and not confined to a single frequency.

The radio occultations were designed to measure the amount of material in the ring plane and provide some indication of particle sizes. Because the best available engineering was applied to this seemingly simple task, and because Saturn turned out to have an unexpectedly complex ring system, the results of these experiments were far more dramatic than even the most optimistic researcher would have imagined beforehand.

Measuring Extinction

***Voyager* simultaneously transmitted two signals with different wavelengths (3.6 and 13 centimeters between radio wave crests). Ring particles of different sizes reduced the signal strength at these two wavelengths in varying but well-understood ways. Thus, by measuring the signals' attenuation at both wavelengths, we learned about particle sizes.**

We also could measure small differences in the times the radio signals were delayed by the particles. Some of the time-delays were only about one ten-billionth of a second, while the largest was about one billionth of a second. These timing effects are also size-dependent, and again, measurements at the two radio wavelengths gave us much more information than would have been possible with one wavelength.

For the radio occultation, the widths of the radio beams at the two wavelengths when they intercepted the particles — about 15 and 30 kilometers — limited our ability to observe fine details in the raw data. But the simultaneous acquisition of the radio intensity and time-delay

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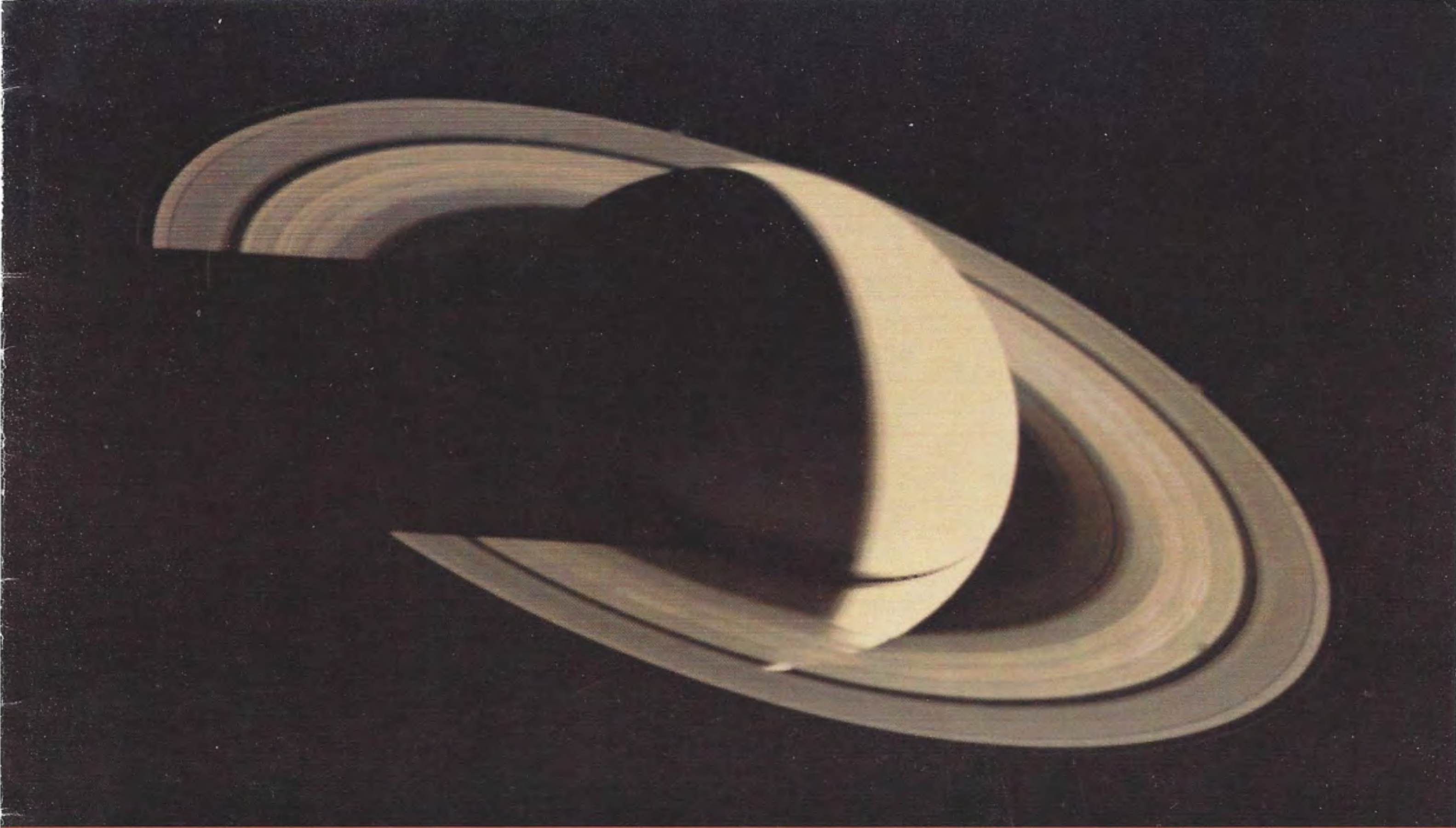
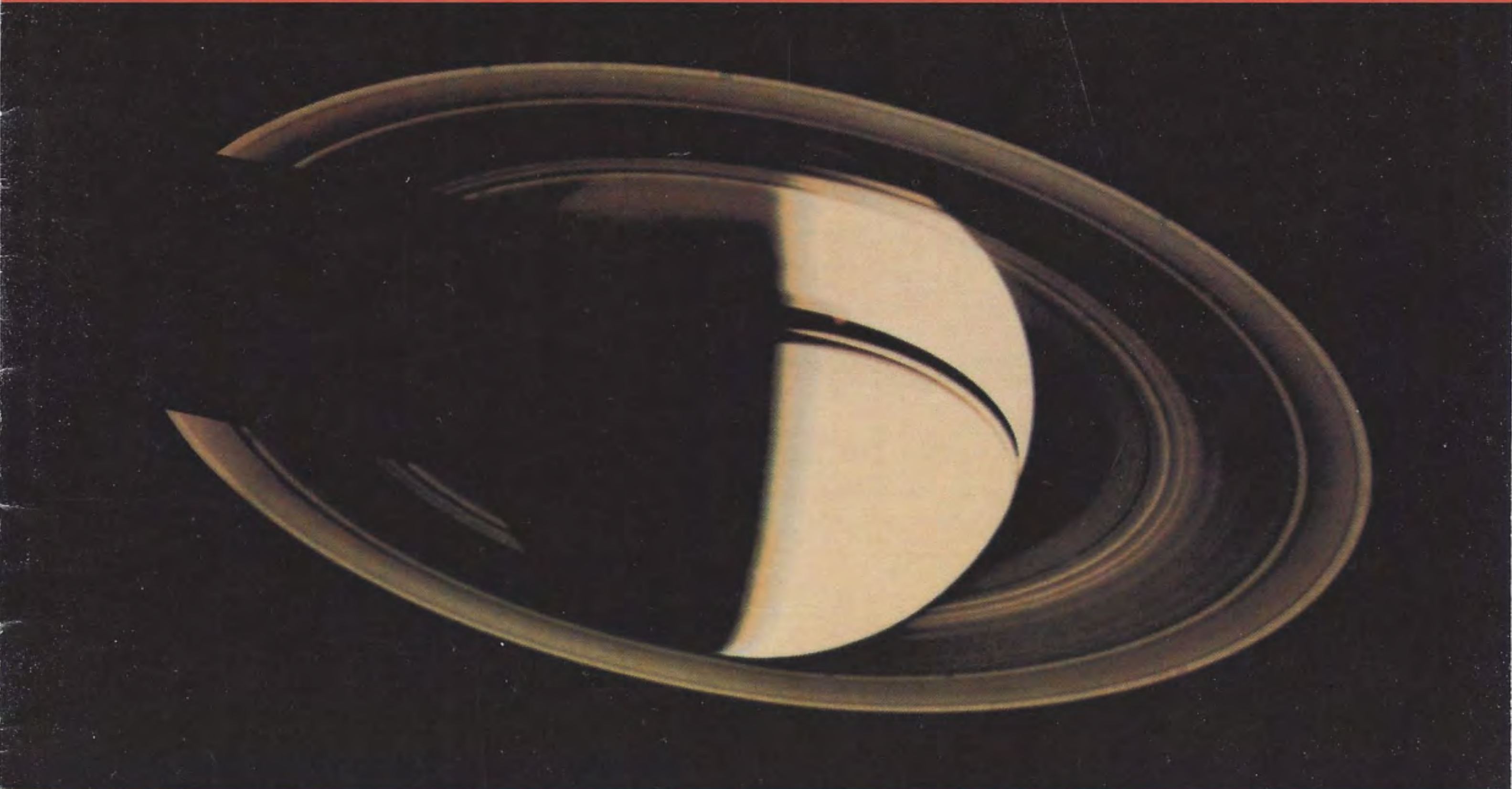




Saturn's magnificent ring system sets it apart from the other planets in our solar system. Thin, dark rings circle both Jupiter and Uranus, and possibly Neptune, but none matches the bright, intricate beauty of the saturnian system. Here, the rings are viewed from two perspectives. In Voyager 1's parting view (top), taken above the rings, sunlight reflects off the icy ring particles, creating a glowing corona about the planet. As it left the system, Voyager 2 saw Saturn from beneath the rings (above). From this perspective, the rings block sunlight falling from above, darkening their appearance. Images: JPL/NASA data permitted us to overcome this limitation, and we could reconstruct the ring structure on a fine scale, using techniques similar to playing back a hologram.

This reconstruction required several days of computation (after several years of design!) but it has given us a map of the rings with details, in places, as small as 50 to 100 meters. By processing the radio data to this fine resolution, we can compare the stellar and radio occultation maps directly. This combination of data gives us multiple benchmarks (at ultraviolet, visible, infrared and two radio wavelengths) on particle sizes.

Thus *Voyager* took measurements of the ring structure with absolute accuracies of only a few kilometers — in a system that spans 280,000 kilometers. This is enough to allow us to test some theories of ring dynamics and evolution.

The radio occultation experiment gave us information on the scattering of the radio waves by particles. Particles deflect waves from the straight-line paths they would normally follow in space. The angles involved are quite small; the largest measured in the *Voyager* experiment was only about 0.7 degree.

The scattering data contained good information on the size of the ring particles. If you had radio eyes, during the occultation, you would have seen the radio signal as a very bright spot in the rings, surrounded by a diffuse, less intense halo corresponding to the scattered signal. The view would be analogous to the corona, or aureole, sometimes seen around the Sun or Moon. The cause would be the same — the scattering effects of particles, in one case, ring particles, in the other, atmospheric particles.

We can relate the aureole's shape to the distribution of particle sizes, giving us the number of particles within a given size range relative to the total number of particles. In Ring A, the largest particles are about 10 meters in diameter — the size of a large boulder. In Ring C, the largest particles are only about 6 meters across — significantly smaller. Unfortunately, much of the signal was absorbed during the Ring B occultation, so we have only scanty information on sizes there.

In virtually all regions of the rings there are many small particles — a great many more small ones than large ones. For every one-meter particle, there are 1,000 of 10-centimeter diameter, and one trillion that are the size of a sand grain.

Collision and Accretion

One explanation for the broad distribution of particle sizes is that it represents an equilibrium between the destruction of old particles by collisions and the creation of new ones by accretion. Calculations of the effects of collisions on ring particles under present conditions indicate that even the largest particles should be completely worn away in a geologically short period — perhaps as little as 100,000 years. If the rings are only a few million years old, and if this estimate is even approximately correct, then all original particles would have been destroyed long ago.

On the other hand, some scientists have argued that material in the present rings should be accreting to form new particles, up to the point where tidal forces from Saturn or some other disruptive mechanism takes over to limit their growth. The present size distribution may result from the competing effects of the forces of combination and disruption. The ten-meter limit may represent the largest size a particle can attain before the disruptive mechanism takes over. This hypothesis agrees with the observation that the largest particles are found in the outer portions of the rings where the disruptive effects of Saturn's tidal forces are weakest.

Growth and Destruction

This question of particle growth and destruction is the type of problem that can be studied by melding the radio and stellar occultation methods. We expect collisional processes in the rings to produce many fine particles, or dust. This dust would be readily detected by stellar occultation, since the photopolarimeter is sensitive to particles about a micron (0.000001 meter) in size. At the same time, such small particles would be invisible in the radio occultation data. So a combination of a large effect in the stellar result and a small or non-existent effect in the radio extinction would be evidence for a region of high collisions. We found such differences in many places in the rings — they are awaiting more detailed study.

Radio scattering and opacity data are affected in different ways by the changes in the rings' thickness. These effects are not predicted by standard theories for waves passing through particulate media and would be extremely challenging to calculate directly from first principles — if that could be done at all. What we can do is numerically simulate radio wave propagation through the rings — that is, do computer "experiments" tracking the paths radio waves would follow through numerous ring models, and then compare the computer results with the observational data.

Using this approach, we found that the rings are surprisingly thin — for example, not more than about 50 meters from top to bottom in large areas of Ring A. The rings are thinner in Ring C, probably more than one particle thick, but a monolayer cannot be ruled out.

SATURN AND ITS RINGS

Saturn's three "classic" rings — Rings A, B and C — have long been known from ground-based observations, as has the Cassini Division, an area separating Rings A and B. Just outside Ring A lies the thin, kinked Ring F, discovered by Pioneer 11. *Other more diffuse rings circle Saturn outside the main system.*

The rings are made up of swarms of icy particles ranging in size from tiny crystals, like those making up an ice fog, to boulder-sized chunks 10 meters in diameter. These particles follow individual orbits about Saturn, although they gently jostle one another and slowly migrate from one orbital path to another, moved by their mutual gravitational attractions and other small forces.

The most heavily populated section is the outer third of Ring B, where we estimate that the number of particles exceeds 10,000,000,000 per square meter. (Remember that most of the particles are extremely small!) In spite of their considerable extent, if melted and then re-frozen in place to form a solid disk, the rings would be only about 50 centimeters thick. As they are, most particles wander no farther than about 50 meters from their mean orbital plane.

Voyager *discovered about two dozen small separations within the classic rings. The spacecraft measurements have also shown that there are many — perhaps thousands — of small fluctuations in the amount of ring material measured at different distances from Saturn. Even the Cassini Division, once believed to be empty, contains a significant amount of material.*

Voyager *also disclosed that the rings are not circular. Several are very slightly eccentric, a further twist in the strange story of Saturn's rings.*

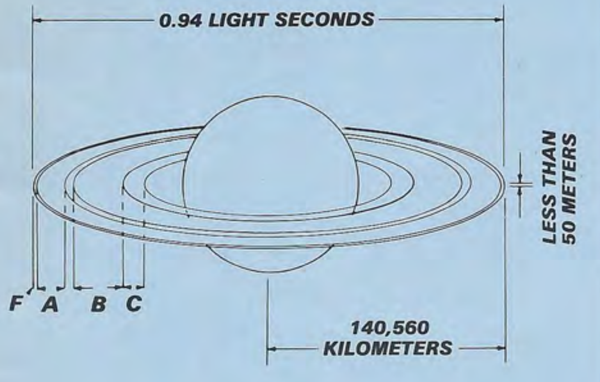
Tantalizing Hints

While the *Voyager* experiments have given us extremely accurate measurements of many ring features — thereby defining more precisely what the rings are — they show conditions only as they existed during the two *Voyager* flybys. Although we now know the dimensions, particle sizes and dynamical structures in the rings, we do not understand how the rings change with time, or how the complex geometry fits together. For example, density waves are associated with the gravitational effects of specific saturnian satellites. These patterns should revolve about Saturn at rates associated with the motion of the controlling satellites. Only tantalizing hints of the time evolution of these patterns could be obtained during the brief *Voyager* encounters.

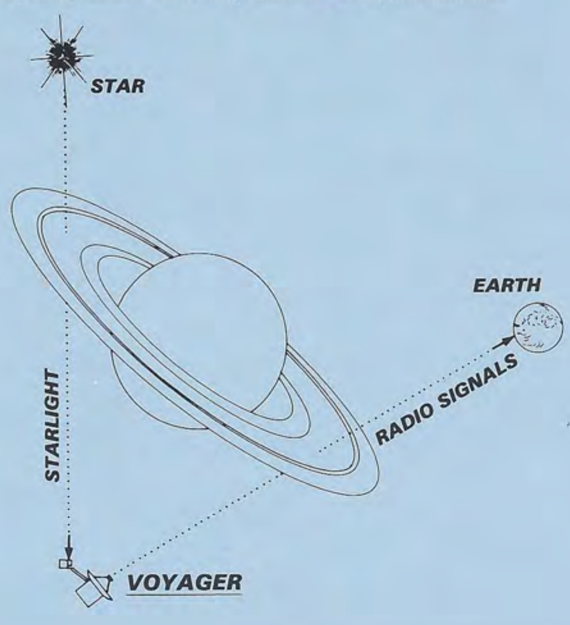
With a spacecraft in orbit about Saturn, we could take frequent occultation and other measurements, allowing us to investigate time and space relationships among the various parts of Saturn's complex rings. Thus, we could greatly extend our detailed knowledge of this exquisite system.

Len Tyler and Dick Simpson are at Stanford University, where they design and conduct radio propagation experiments for planetary studies. Both are participating in the Voyager *project.*

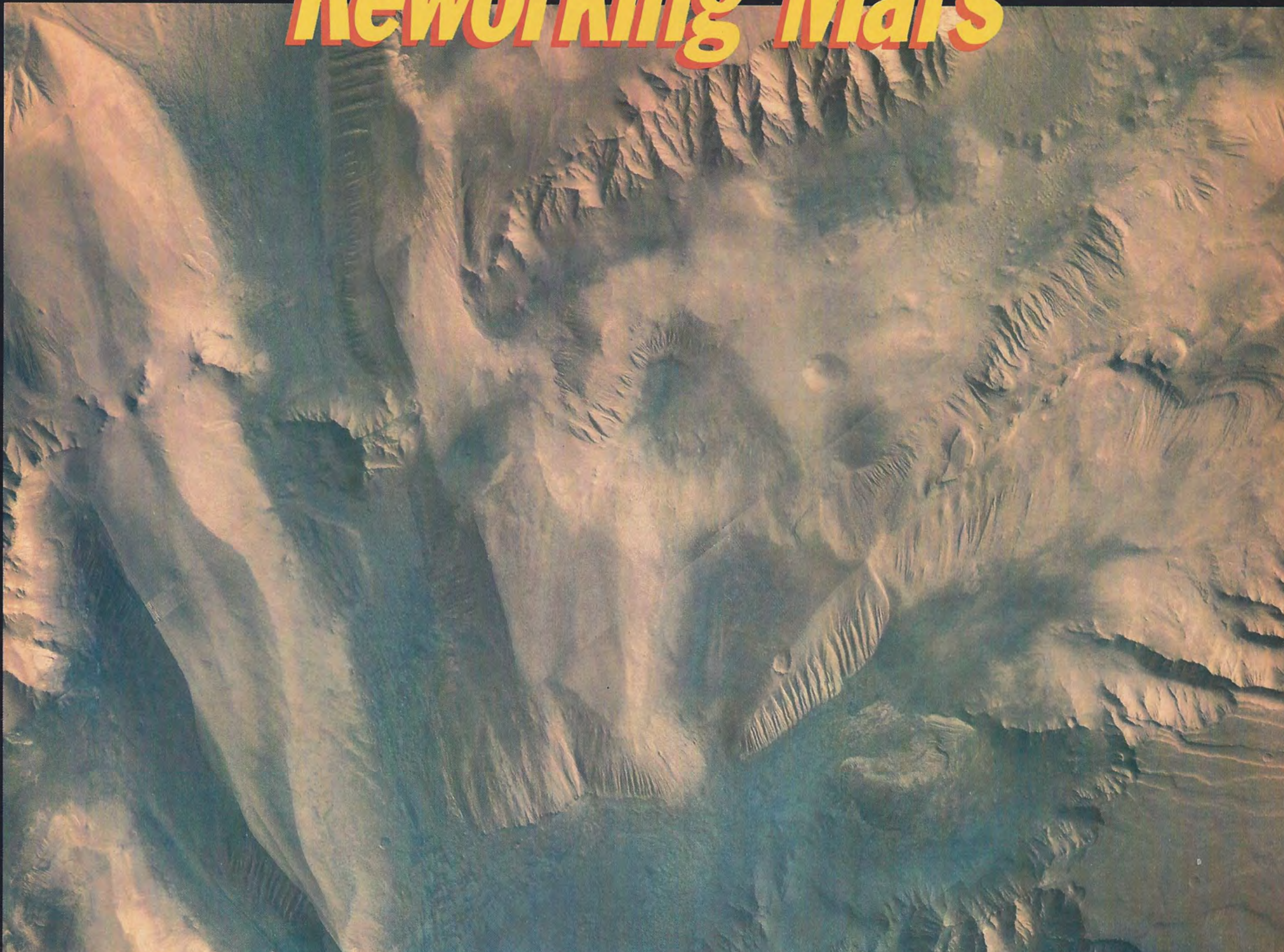
Radio occultation data have been used to construct images showing the distribution of particles in Saturn's rings. This shows a representation of the outer portion of Ring A, covering a region one meter in diameter and showing particles larger than two millimeters. The white "particles" have the same relative size distribution as ring particles, but the real particles are probably irregularly shaped.

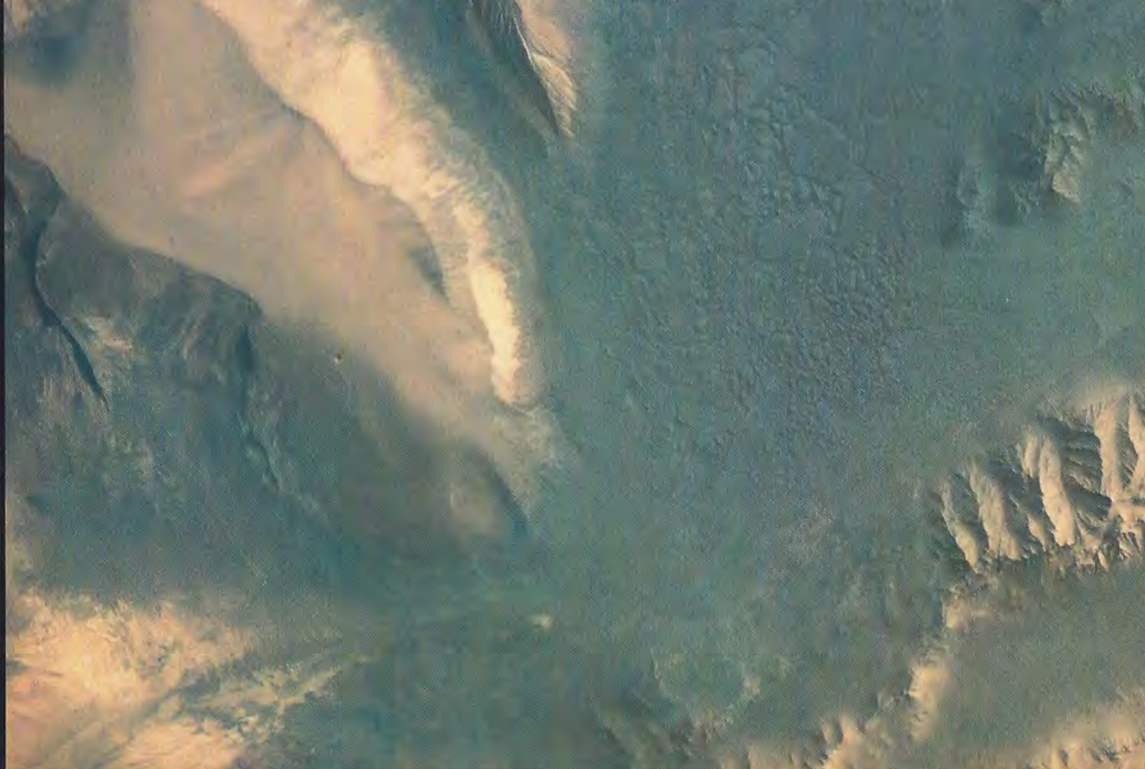


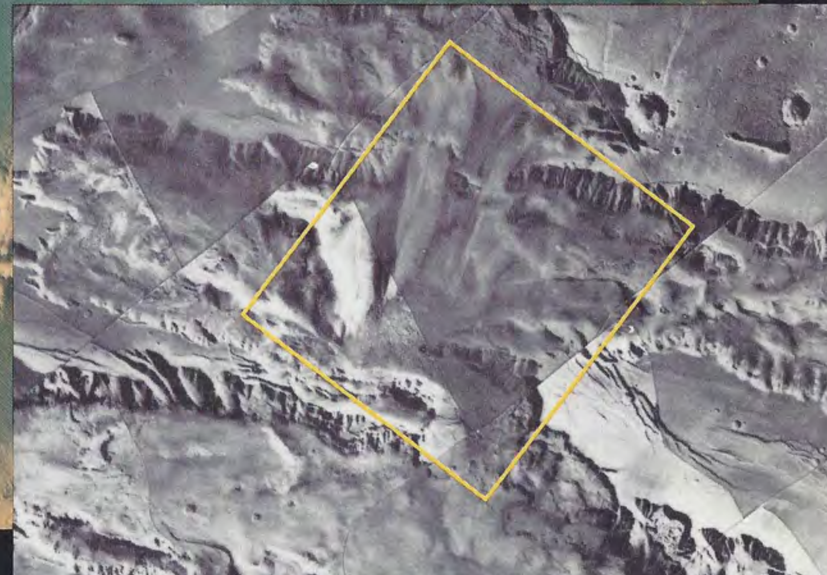
Stellar occultation (left) uses light from a star as viewed with a small telescope — the photopolarimeter — on Voyager. *The photopolarimeter measures the amount of starlight reaching it as the star appears to pass behind the rings. Radio occultation (right) uses microwave signals transmitted from* Voyager *to probe the rings. The signals are received by NASA tracking stations on Earth. These experiments are conceptually similar but vastly different in implementation.*



Reworking Mars







The color scene covers an area 204 by 236 kilometers (outlined on the black-and-white mosaic). The image is slightly rotated so that north is about 40 degrees clockwise from the top.

The spacecraft may die, the mission may end, but the scientist's work goes on. *Viking* Orbiter 2 stopped transmitting to Earth in 1978; *Viking* Orbiter 1 ran out of gas in 1980. They left voluminous files behind them, and scientists are still scrutinizing the data and gleaning more information on Mars. Although *Viking* is sending us no new images, advanced computer techniques enable scientists to rework the data — combining images, adjusting color and contrast — to bring out details and create new views of the martian surface.

This is an image of Candor Chasma, a part of Valles Marineris, the huge canyon network stretching almost one-quarter of the way around Mars. At the United States Geological Survey in Flagstaff, Arizona, Alfred S. McEwen created it by "multiplying" detailed black and white images by low-resolution color images. (See the January/February 1984 *Planetary Report* for a description of this process.) The colors here are enhanced, but the relative colors are correct; that is, the blue areas are actually bluer than the red areas. But in true color, all of Mars is reddish.

Like the smaller Grand Canyon of Earth, Valles Marineris has much to tell us about its planet's geology. This region, in particular, contains features that are explained in different ways by different scientists.

Layered sedimentary deposits, several kilometers thick, lie in the center of this image. The layering may be controlled by cyclical changes in the martian climate. These sedimentary rocks are soft, and so are easily streamlined and fluted by the wind.

Mike Malin of Arizona State University has proposed that these layers were formed in Mars' early history, when it was blanketed by a thick atmosphere. Today Mars is famous for its planet-wide dust storms, but even larger storms once may have encompassed the planet, laying down thick layers of dust. Interbedded with the dust might be lava flows or layers of flood debris. Over millions of years, these processes may have formed the sedimentary layers now exposed by the faulting and erosion that created the canyon.

In 1977, John McCauley of the USGS proposed an alternative hypothesis: These layers formed on the floors of ancient lakes that once filled parts of Valles Marineris. McCauley speculates that Ophir Chasma (the canyon to the north of this region in the black-and-white mosaic) and Candor Chasma were once separate lakes, until their shores were breached, forming the north-south trending channels in this scene.

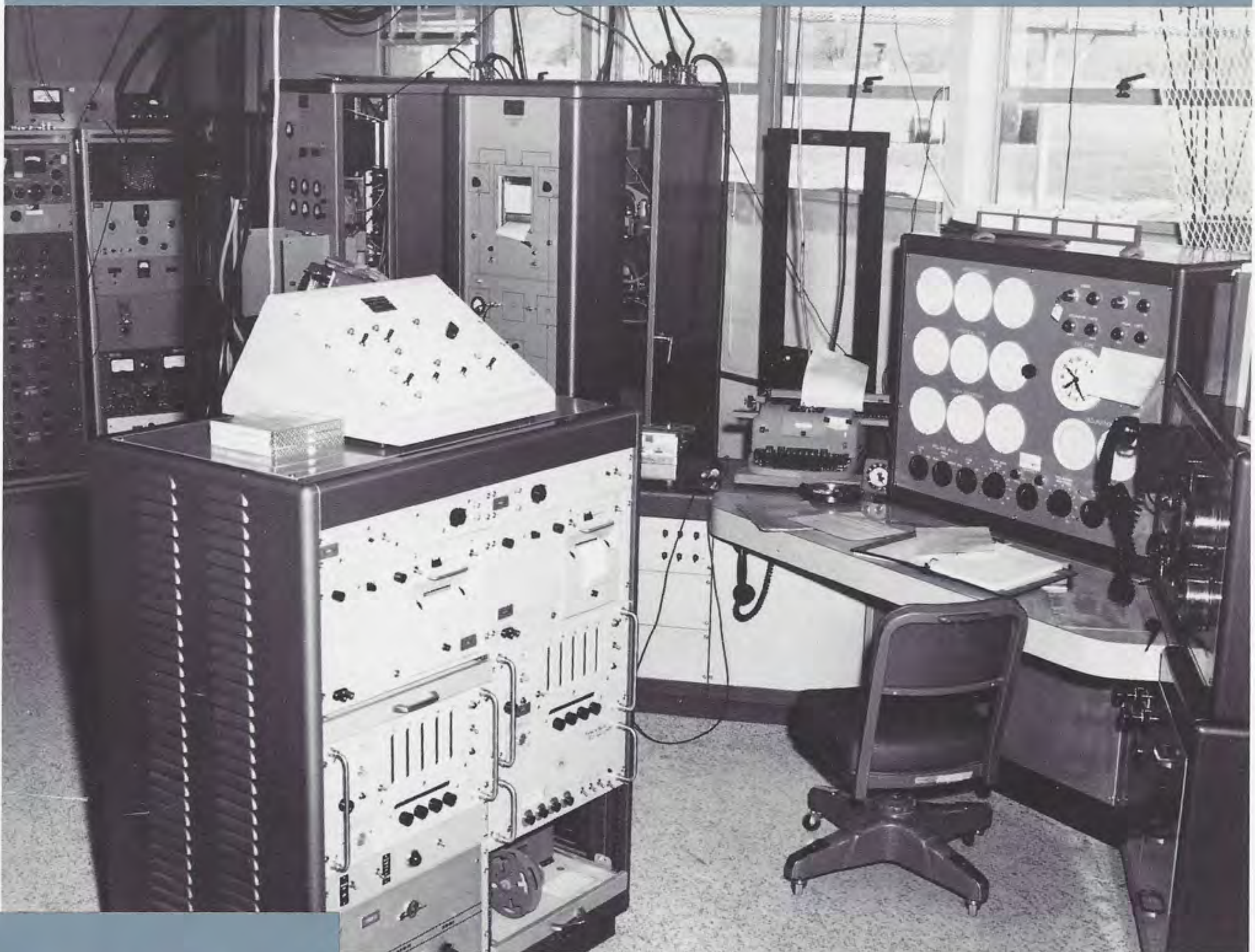
Baerbel K. Lucchitta, also of USGS, recently suggested that the dark blue material in this image, and elsewhere in Valles Marineris, is volcanic ash erupted from nearby vents. These very young deposits overlie older erosional features within the canyons.

Someday new spacecraft — or human explorers — will again land on Mars and resume our exploration of this neighboring planet begun by the *Mariner* and *Viking* probes. Harold Masursky of USGS has proposed the region in the upper left corner of this image as a possible landing site. Until we return to Mars, the debates and discussions about this fascinating region will continue. — CHARLENE M. ANDERSON

Twenty-five Years of Searching

SETI Scientists Celebrate an Anniversary

by Woodruff T. Sullivan, III



This is the receiving equipment and telescope control desk for Frank Drake's Project Ozma at the National Radio Astronomy Observatory at Green Bank, West Virginia. For three months in 1960, Drake tuned a single channel to the 21-centimeter line of hydrogen. He alternately pointed the 85-foot dish antenna at two nearby Sun-like stars, Tau Ceti and Epsilon Eridani.
Photo: Woodruff T. Sullivan, III

Twenty-five years ago astronomer Frank Drake spent three months searching for signals from nearby stars Tau Ceti and Epsilon Eridani, and ushered in the modern search for extraterrestrial intelligence (SETI). Scientists recently celebrated the anniversary of this pioneering experiment with a workshop held at the National Radio Astronomy Observatory at Green Bank, West Virginia.

In the shadow of the 85-foot radio dish originally used by Drake, about fifty scientists traded ideas, data and opinions. Although they reached no consensus on the ideal strategy, the participants did agree that SETI, now a generation old, is thriving. And because it thrives, the human species is embarked on an adventure of fundamental importance.

Workshop participants also honored Sebastian von Hoerner upon his retirement. In his keynote address, he called SETI the next great task of humankind, yet he views it as simply another logical step in our increasing ability to handle information. From the genetic code of DNA to the evolution of ever-larger brains, from the invention of language and writing to the development of ever-smarter computers, SETI seems a natural extension of what we've been doing all along.

Even if it takes us thousands of years to find a signal, according to von Hoerner, SETI's most profound benefit may be that it forces us to view ourselves with a cosmic perspective. This new view may lead to novel solutions to our civilization's perplexing problems. As von Hoerner asked, "How could you begin to explain our society to a little green man who had just landed? Would he really class as 'intelligent' any species that had manufactured and was holding in readiness for each member the equivalent of three tons of TNT?"

The best strategy for establishing contact with an extraterrestrial civilization, SETI researchers generally agree, involves patient listening with large radio antennas at microwave frequencies similar to those used in your home oven and for satellite communications. A substantial portion of the meeting thus centered on radio observations now in progress or planned for the near future.

Robert Gray, representing a small, but growing, group of amateur SETI experimenters, reported on a 12-foot dish and 21-centimeter wavelength receiver in the backyard of his Chicago home. While such a setup is far less sensitive than the systems used by professional astronomers, Gray pointed out his advantages of more observing time and quick coverage of the entire sky.

The cosmic haystack that we comb for the SETI needle is so vast that there's room for a wide variety of careful observations, including those from amateurs (see the April, 1985 *Sky & Telescope*). Another remarkable effort comes from Robert Stephens, who bought, at five cents each from military surplus, two 60-foot antennas in the Canadian Arctic. He is now seeking funds to carry out an extended SETI program.

Only two professional SETI programs are now actively collecting data. For the past decade, the giant antenna at Ohio State University, no longer used for radio astronomy, has been sweeping the skies for signals at the 21-centimeter wavelength. (Many researchers favor this wavelength as a natural communications channel because the hydrogen atom — the most abundant in the universe — naturally emits at this frequency.) Robert Dixon and his volunteer staff, with a 50-channel receiver, have collected data containing 30,000 candidate signals meeting various criteria. These signals have been analyzed and often followed up, but although several anomalies remain, nothing has yet emerged as a reproducible signal. The Planetary Society is helping to support these observations as part of our SETI program.

The other effort, generously supported by The Planetary Society, is Paul Horowitz' Project Sentinel, using an 84-foot dish

(continued on next page)

Frank Drake and Project Ozma: The Search Begins

In 1958 Frank Drake was one of the first staff members of the new National Radio Astronomy Observatory at Green Bank, West Virginia. He was interested in observing 21-centimeter radio radiation to investigate magnetic fields and particles in space and around other planets. The new 85-foot dish at Green Bank had been designed for just these sorts of observations.

But Drake also had a life-long interest in the possibility of life on other worlds and realized that observations on radio wavelengths might be the ideal method to detect other civilizations. Because new devices had recently been invented to amplify very weak radio signals, Drake knew that the time had come to consider the search for extraterrestrial intelligence (SETI) experimentally as well as theoretically.

In March 1959 he proposed to Lloyd Berkner, the acting director of the observatory, that a search for alien radio signals coming from nearby Sun-like stars be planned. Berkner's encouraging response was shortly echoed by the distinguished astronomer Otto Struve, who had been named the observatory's first director. Struve's appointment was a stroke of good fortune for Drake, since Struve's work on slowly rotating stars had been seminal in suggesting that many other stars were accompanied by planets. Struve was more receptive to the idea of SETI than many other astronomers were at that time.

Project Ozma was named for the princess of the imaginary land of Oz, from the series of books by L. Frank Baum, "a place very far away, difficult to reach, and populated by exotic beings," as Drake put it. His decision to search at 21 centimeters was based on the practical consideration that this wavelength was a prime focus of the observatory's normal work. But later that year, Cocconi and Morrison independently published their famous letter to the journal *Nature* arguing on theoretical grounds that searching at 21 centimeters was "the uniquely rational way" to look for extraterrestrial signals.

By April 1960 Drake had completed his set-up. Two receivers at the focus of the dish observed a target star and the nearby background. By switching back and forth rapidly between the two receivers, the background signal could be determined and subtracted. Since Drake thought that intelligent signals would be narrow-band, another device subtracted any broad-band signals electronically. Then, a parametric amplifier boosted any remaining signal.

The two stars targeted were Tau Ceti and Epsilon Eridani. Each is a Sun-like star about 11 light years from Earth. On April 8 at 4:00 am, the dish was pointed at Tau Ceti. No signals were detected. Several hours later the dish was shifted to Epsilon Eridani — and strong signals immediately began coming in! Very wisely, Drake refrained from making any public announcement and proceeded to check for possible sources of human interference. As it turned out, Ozma had detected a secret military experiment that was using airborne transmitters to test radar countermeasures.

The two stars were observed over the next few months and no alien signals were detected by the project's end that June. But modern SETI had begun, and aided over the following years by Drake's enormous experimental and theoretical contributions, it has continued. As Drake, now a Planetary Society advisor, said, "Those who feel that the goal justified the great amount of effort required will continue to carry on this research, sustained by the possibility that sometime in the future, perhaps a hundred years from now or perhaps next week, the search will be successful."

—Jon Lomberg

Paul Horowitz's Project Sentinel, supported by The Planetary Society, uses a dish and operating wavelength similar to Ozma's 25 years before, but its 128,000 channel capacity and more sensitive receiver enable a much greater range of signals to be detected. Project META will soon expand this capability to 8 million channels; 4 million are shown in the inset.

Photos: Paul Horowitz; Frank Siteman (inset)

owned by Harvard University. His strategy also centers on the "magic" 21-centimeter wavelength, but differs from the Ohio State approach in that 128,000 channels are simultaneously monitored. Sentinel can best pick up very sharp signals (with their energy concentrated at a very precise wavelength), but it requires considerable electronic dexterity to handle the incredible flow of numbers. For two years Sentinel has scanned the northern skies, and this autumn Horowitz will switch over to an even larger system. The rapidly advancing capabilities of electronics and special-purpose computers will enable the new analyzer, dubbed META for Megachannel Extraterrestrial Assay, to monitor eight million channels!

NASA's SETI program, led by Bernard Oliver of Ames Research Center and run jointly with the Jet Propulsion Laboratory, has also taken significant strides forward. This program's goal is a two-pronged search over five years. In one approach, a 100-foot dish will scan the entire sky over a wide range of wavelengths. The second approach will focus on nearby Sun-like stars and the 21-centimeter hydrogen line. Current efforts center on design and testing of the software and hardware needed to do the complex signal acquisition and analysis.

The dish of Harvard University's Oak Ridge Observatory, home of Projects Sentinel and META, looks out from the countryside near Harvard, Massachusetts. *Photo: Frank Siteman*

This NASA program could detect not only signals concentrated at a particular frequency, but also signals drifting in frequency or pulsed signals over a broad range of frequencies. Project researchers hope to finish designs soon and start building a system to begin observations in the early 1990's.

Gerritt Verschuur gave a fascinating talk on some ethical considerations that arise as soon as we contemplate SETI. He argues that we are irresponsible when we conduct SETI experiments without first considering the possible consequences for us or, more particularly, our descendants. Would the human race become demoralized upon detecting a super-intelligent race? Who should decide whether we send a response? What should such a response be? Because of the vast interstellar distances, most scientists have not considered two-way communication, but think only about picking up a one-way signal, much as an archaeologist receives a "signal" from ancient Troy. But surely what starts as one-way communication will *eventually* evolve into a conversation.

Although most SETI researchers feel that these kinds of questions are not appropriate for discussion at scientific meetings, Verschuur reminded the audience that scientists developing the atomic bomb during World War II felt much the same way. In that case, only when they had achieved their goal did they start asking broader questions — and wondering why they had not asked them earlier. This is not to equate the ethics of SETI with those of the bomb, but simply to state that perhaps ethical questions should receive more attention.

In concluding the workshop, both Drake and von Hoerner noted that it is amazing that SETI is alive and well after a quarter of a century — without a single positive result. Furthermore, the field has attracted cadres of new workers along with the loyal pioneers of the 1960's. New technology allows searchers to work a billion times faster than in the old days. More important, scientific attitudes have changed so that SETI is no longer viewed as a speculative waste of time.

And yet, as George Swenson pointed out, the essential dilemma of SETI is that it addresses one of the most fundamental questions we can ask, but our experiments are little better than shots in the dark. Yet shots in the dark sometimes hit their marks. Although workshop participants disagreed over SETI strategy, they reached a consensus on one thing: For the first time in our history we possess the scientific tools to acquire a preliminary answer to the question "Are we alone?" So let's get on with it.

Woodruff Sullivan is an astronomer at the University of Washington, Seattle. Besides SETI, his research interests include galaxies and the history of astronomy.

World Watch

by Louis D. Friedman

Often at Planetary Society events or in mail to our office, we are asked, "Does The Planetary Society lobby?" Depending on what the questioner means by "lobby," the answer could be: yes, no, maybe, occasionally or rarely. We have preferred to conduct ourselves as a public interest group, disseminating information about planetary science and exploration, rather than as a special interest group trying to "work the Washington scene." We have no Washington office and rarely are found with power brokers in posh restaurants or bars. We have never hired a public relations or lobbyist firm, and have never spent money on a political campaign.

On the other hand, Society officers have frequently testified to congressional committees and have briefed the staffs of Congress, the President, the Office of Management and Budget and NASA. Frequently and regularly, we provide information packages, including *The Planetary Report*, to key decision makers. Our large public events, such as Planetfest '81, the January space weapons symposium and, most recently, the Steps to Mars conference, invariably draw political and media attention.

Sometimes our activity is more focused. In 1980, members of the then-fledgling Planetary Society sent 10,000 letters to President Reagan, urging a US mission to Halley's Comet — to no avail. To the best of our knowledge, not one of these letters was ever answered. Several times in the following years, when the entire planetary program was being threatened, our members wrote letters, using information provided by the Society, to congressmen, newspapers, magazines and NASA, supporting continued planetary data analysis, tracking the *Voyager* spacecraft, sending *Galileo* past the asteroid Amphitrite and continuing the Venus Radar Mapper. We believe, and have been told, that we did help turn around this administration's early position against planetary science. We are now pleased with Washington's evident revival of modest enthusiasm for solar system exploration.

When Congress forbade NASA to conduct the search for extraterrestrial intelligence (SETI), we marshalled our forces. Dr. Sagan and others at the Society contacted members of Congress and convinced them that this search is important. The following year, Congress reinstated NASA's SETI program.

At the same time, the Society initiated its own highly visible and powerful Project Sentinel at Harvard University's Oak Ridge Observatory, under the direction of Professor Paul Horowitz.

Our support of NASA's activities might be called lobbying, but such focused efforts are rarely necessary. Only a few times in the Society's five-year history have we actually lobbied. As a non-profit, tax-exempt organization, The Planetary Society is allowed to lobby a small amount of time with a limited amount of its budget, generally considered to be five percent. The time and money we have spent in lobbying is less then one percent.

One recent bit of lobbying also concerned the SETI program. It did not involve the President, Congress, NASA or anyone else in Washington. Instead, it was centered on the planning board of Boxborough, Massachusetts, a rural town of about 2,000 people, northwest of Boston.

The Raytheon Corporation had asked the Boxborough planning board for a zoning variance to build a radar weather station on the outskirts of town. They proposed a large instrument, with 750 kilowatts of power and an antenna tens of meters in diameter. Normally, this issue would not concern us. But three days before the planning board meeting, Professor Horowitz learned that the proposed radar would be on a direct line-of-sight with with the Oak Ridge radio telescope. If the Raytheon radar were to look directly at our telescope, it would burn out the receiver! Even when turned away, its interference would overwhelm our sensitive receiver, making Project Sentinel untenable.

Thus we had a very great interest in lobbying against this minor zoning variance in a small town in Massachusetts. If the radar weather station were built as proposed the world's most advanced, continuously operating SETI project would have to be scrapped.

One advantage to being a large public membership organization is that we have members everywhere, including people in Boxborough and two adjacent towns, Littleton and Harvard. The planning meeting was scheduled for a Monday. On Sunday night, we wired all Society members living in these three towns, telling them of the issue. We asked that, if possible, they attend the meeting to register the Society's interest in seeing the Oak Ridge SETI program continue. They answered our call, and half the audience at the meeting was made up of Planetary Society members.

Professor Horowitz also attended the meeting and made an eloquent statement in support of his project. Raytheon, a major employer in the area, presented its case, arguing the value of weather radar. But the planning board refused to permit the variance, and told the Raytheon people that, before they could take their project any farther in Boxborough, they would have to work out technical arrangements with The Planetary Society.

Professor Horowitz and Raytheon engineers met and worked out an agreement. If Raytheon were to go ahead with the radar, and if the zoning variance were to be granted, it could be built only with these provisions:

- ☐ Raytheon would install equipment at the Oak Ridge radio telescope to monitor interference from their radar.
- ☐ Raytheon would install equipment to protect our radio telescope from burn-out.
- ☐ The Raytheon radar would operate only 40 hours per month, thereby leaving the rest of the month available for SETI observations.
- ☐ The Raytheon experiment would be conducted for only one to two years.

But this compromise may be unnecessary. The Raytheon Corporation has decided that it will probably locate the radar station somewhere else. They have received approval to build the radar at two other possible sites, which they now say they prefer for technical reasons. The opposition of the Boxborough community, including Planetary Society members who attended the planning meeting, also played a role in this decision.

It would have been irresponsible for The Planetary Society to insist that the weather radar project not be allowed at all; Earth is finite and we must recognize others' needs, even if they conflict with ours. It would also have been irresponsible for Raytheon to have proceeded with its original plans and wiped out the exciting and important SETI project. But radio interference is now a fact of life and, ultimately, it will push SETI off our planet, perhaps to the far side of the Moon or elsewhere in space where telescopes can search with less interference.

We salute our members in Boxborough, Littleton and Harvard who came to the planning board meeting to lobby for The Planetary Society. And, as always, we are honored by the hard work and dedication of Professor Horowitz. Under his direction, Project META will be initiated on September 29, 1985.

Louis Friedman is Executive Director of The Planetary Society.

News & Reviews

by Clark R. Chapman

While much of the southwestern United States sweltered in late-June heat approaching 110 degrees Fahrenheit, astronomers gathered in cool Flagstaff, Arizona, beneath the snow-capped San Francisco Peaks, to discuss comets and asteroids. Co-hosted by world-famous Lowell Observatory, the 97th meeting of the Astronomical Society of the Pacific (ASP) was held on the high, pine-forested campus of Northern Arizona University. The ASP is an organization of astronomers, both amateur and professional, primarily from the western states. With the impending arrival of Halley's Comet, it was natural that the small bodies of the solar system would be the theme for this year's ASP meeting.

Some of the most surprising results reported in Flagstaff concerned ground-based radar observations of asteroids. Steven Ostro of the Jet Propulsion Laboratory has been using the giant radar dish in Arecibo, Puerto Rico, to bounce echoes off some of the nearer and/or larger minor planets. For some years, asteroid spectroscopists had been intrigued by the fact that the 250-kilometer asteroid Psyche (asteroid number 16) has the "color" of metal. Since it is difficult to believe that natural processes could have refined cosmic material into such an enormous hunk of iron, the metallic color had been conservatively attributed to tiny metal flakes distributed within a translucent, colorless mineral, just as in the enstatite chondrites — a type of meteorite that does contain proportions of iron and rocky minerals resembling those thought to have been in the nebula from which the solar system formed. But Ostro's radar results, also reported this summer in *Science* magazine, show that the more exotic model for Psyche is probably right. "Anyone trying to make Psyche out of enstatite chondrites," Ostro told his Flagstaff audience, "is on very thin ice."

Echoes from a Dead Comet?

Just as intriguing are Ostro's radar echoes from the small object Adonis, which is in an elongated comet-like orbit crossing our own planet's path. Radar pulses from Arecibo are usually transmitted in a circularly polarized sense and the echoes normally come back with the "handedness" reversed. (You can use polarized eye-glasses to observe an optical analog of how reflections affect the polarization of electromagnetic radiation.) In the case of Adonis, however, a large fraction of the Arecibo radar echo came back in the *same* polarization sense as the transmitted signal! Nobody — least of all Ostro — claims to know, for sure, what these data mean. But Ostro was willing to speculate, during the question-and-answer period following his ASP talk. He thinks that the radar wave must be *refracted*, or bent around 180 degrees within the surface layers of Adonis, rather than being reflected directly from the small body's surface. A very porous material, with the structure of Styrofoam, may be able to perform this unusual feat. Perhaps Adonis was once an active comet, but its ices have all evaporated after thousands of passages through the warm, inner solar system, leaving behind a residual foam-like bonded matrix of solid grains. Through the big dish in Puerto Rico, we may now have a clearer, though still speculative, glimpse of what a dead comet is really like.

Whether they are dead comets or fragments of main-belt asteroids, the Earth-crossing Apollo asteroids continue to intrigue us . . . and threaten us! In their game of cosmic roulette with Earth, they certainly crash into our planet from time to time. A few tens of thousands of years ago, one metallic chunk from an object like Psyche struck southeast of Flagstaff, creating Meteor Crater. Although giant impacts, of the sort that could create a natural version of nuclear winter or render species extinct, occur much less frequently, such an impact *could* happen any time. A recent popular review of the impact probabilities, written by Eugene Mallove, is in the July issue of *Technology Review*, the magazine published by the Massachusetts Institute of Technology.

A Preview of Distant Moons

This coming January, the *Voyager 2* spacecraft will sail past the planet Uranus and its retinue of at least five moons. Uranus is the next-to-last destination for the historic *Voyager 2* mission, which — along with its twin, *Voyager 1* — yielded a wealth of data about Jupiter and Saturn some years back. As usual, the impending visit of a spacecraft to a planet has caused earthbound astronomers to redouble their telescopic efforts. Of course, there is the need to study the Uranus system to best plan *Voyager's* observing sequences during encounter. An unspoken but potentially more powerful psychological impetus behind astronomers' new interest in Uranus and its moons is the hope to "beat" *Voyager* and make some historic discoveries before the spacecraft arrives. Astronomers fear that there will be little left for them to do after the close-up spacecraft studies, despite the fact that *Voyager's* earlier reconnoitering of the giant planets Jupiter and Saturn left plenty of new mysteries open for telescopic study.

In the July *Scientific American*, astronomers R. Hamilton Brown and Dale Cruikshank write about many fascinating things that may, or may not, be true about the uranian satellites. They move onward to *Voyager's* final target, the planet Neptune and its planet-sized moon, Triton. Finally, they treat the double planet, Pluto, despite that distant planet's absence from *Voyager's* itinerary. Pluto's inclusion in a story of moons is justified by recent speculation that it may be a sibling of Triton; Pluto and its close companion Charon remain in an independent orbit around the Sun while Triton was somehow captured into orbit about Neptune.

It is remarkable how much information has recently been gleaned about these distant satellites, for only a few years ago the only facts known were their orbits, approximate brightnesses and names. Yet the data are necessarily inexact because of the faintness of these objects in even the largest telescopes. Many of the speculations by Brown and Cruikshank could fall by the wayside after *Voyager's* visit.

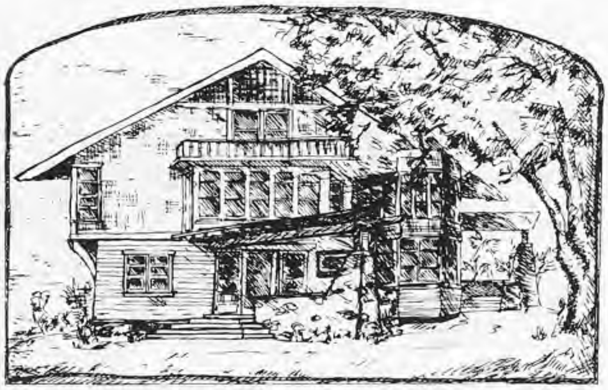
Still, it is fascinating to think about some of the possibilities: Methane-rich water ice blackened by galactic gamma rays; water volcanos erupting under *Voyager's* watchful eye; methane ice fields (frozen marsh gas), oceans of nitrogen . . . The outer planet satellites hover in the frigid emptiness of our planetary system, illuminated by a dim and distant Sun, waiting to give up some of their secrets to the first mechanized visitor from Earth.

Because of the lengthy travel times, even at ten times the speed of a rifle bullet, subsequent missions to Uranus and Neptune are likely to be even less frequent than the occasional return trips to nearer planets like Mars. So planetary astronomers will have plenty of opportunities to follow up *Voyager's* discoveries as ground-based and Earth-orbital instrumental techniques continue to improve. In the meantime, we can marvel at what Brown, Cruikshank and their colleagues have already learned about outer-planet moons as we await *Voyager's* arrival at Uranus.

Clark R. Chapman, a regular columnist for The Planetary Report, *is a planetary scientist residing in Tucson, Arizona.*

NEW HEADQUARTERS FOR SOCIETY

Members who visited the old Planetary Society offices know that our staff and activities had long since outgrown the available space. So, we are delighted to announce our move to new headquarters at 65 N. Catalina Avenue in Pasadena.



DRAWING: S.A. SMITH

The building is a large 1903 frame house, now converted to offices, designed by the renowned Pasadena architects Charles and Henry Greene. Volunteers and visitors will be welcome in our new home.

"STEPS TO MARS" A SUCCESS

"Steps to Mars," the July conference jointly sponsored by The Planetary Society and the American Institute of Aeronautics and Astronautics was a tremendous success. We received press coverage across the United States, including an Associated Press story and a feature in *Time* magazine. Society Executive Director, Louis Friedman, appeared on the *Today* show.

The event's highlight was the appearance of the Soviet *Apollo-Soyuz* cosmonauts and their counterpart American astronauts, who were feted in a 10th anniversary celebration of their mission. At the invitation of The Planetary Society, Alexei Leonov and Valery Kubasov joined with Tom Stafford, Deke Slayton and Vance Brand in a special ceremony recognizing their successful cooperative mission in space.

A panel discussion, "Humans to Mars — Why?", featured the Society's President Carl Sagan and Advisors Sally Ride and Harrison (Jack) Schmitt, and was moderated by Vice President Bruce Murray. Other panelists were James Beggs, NASA Administrator, and Roger Bonnet, Director of Space Science for the European Space Agency.

Senator Spark Matsunaga (D-HI) spoke in favor of a 30-year program to put humans on Mars, and proposed that 1992 be designated as the International Space Year. He introduced an ISY resolution to Congress on the following day.

As the conference closed, many enthusiastic members told us that they agreed with Dr. Sagan that "something happened here today," and they look forward to the future and Mars.

MARS CONTEST WINNERS ANNOUNCED

The 1985 Mars Institute student contest has been won by Jeff Bytoff, a computer science major at the University of California at San Diego. He received a free trip to the "Steps to Mars" conference where he was presented a check for $1,000.

The winning paper, "Energy Transmission Satellites in Mars Synchronous Orbit," explored placing solar energy collectors and transmission satellites, made from materials mined on Phobos and Deimos, in orbit about Mars.

The topic for this year's contest was "Mars Moons Mission Concepts." Entrants were asked to address the roles the moons might play in the exploration of the planet. The papers were judged by six eminent space scientists.

A team of five students from the University of Colorado at Boulder took second place and won $250 for their paper, "Phobos-Deimos, A First Manned Mission to the Mars System." The team included Douglas Jones, Wayne Pryor, Michael LaPointe, Helen Hart and Steven Jones. Lapointe, Hart and Doug Jones were on the team that won last year's contest.

DEDICATED VOLUNTEERS HELP SETI

Thanks to the generosity and hard work of two dedicated Society members, the Oak Ridge radio telescope at Harvard, Massachusetts has undergone a dramatic "facelift." Last year Mal Jones of West Tisbury, Massachusetts and Mike Williams of Coupeville, Washington approached Professor Paul Horowitz, developer of Project Sentinel and META, to offer whatever help they could. Because the telescope had become "quite rusty and almost unsafe," according to Horowitz, what was most needed was "to restore the telescope to good health."

So, Mal and Mike (who were not previously acquainted,) spent three weeks last fall scraping, sanding and priming the instrument. They used a floodlight to help them work nights and a cherrypicker to reach most of the telescope, whose dish is 84 feet across.

Mal is committed to many causes, in addition to SETI, such as ecology and conservation. A prolific inventor, he lives in an inventor's paradise surrounded by his own creations — including a submarine. Since Mal is mechanically adept, he restored the telescope's pulleys, doorways and latches to good shape.

Mike donated $2,000 to the META project and drummed up an additional $5,000 from friends. He has a background in civil engineering and has always been interested in astronomy. On top of the painting and fundraising, he also did quite a bit of soldering on the electronics boards.

The Oak Ridge telescope is now a gorgeous, gleaming silver and in fine working order. For a finishing touch, Mal painted a striking flag of the Earth, the Sun and Moon on the telescope's pedestal. It's ready for META's initiation in the fall, and then to work!

CALENDAR OF SOCIETY EVENTS

November 26, 1985 — The Planetary Society presents a television special on Halley's Comet to be broadcast on most Public Broadcasting System stations in the United States.

December 6, 1985 — "Comet Quest," an international symposium on comets, Langley Theater, National Air and Space Museum, Washington, DC.

January 24, 1986 — "Uranus, The Voyage Continues," a symposium at Beckman Auditorium, the California Institute of Technology, Pasadena; a *Voyager* Watch will also be conducted.

GALILEO ORBITER AT IO — The *Galileo* orbiter rushes past Io just hours before it enters orbit about Jupiter. Artist James Hervat comments: "In making this painting I sought to portray Io's actual visual appearance from near space. When Io's reflectivity is considered (its measured albedo exceeds that of brilliant Venus), I feel the familiar, vivid "pizza" colors of the enhanced *Voyager* images would fade into pastel shades of tan and yellow surrounding the darker volcanic regions." Scientists have recently been debating Io's true colors; the controversy may be settled in 1988 when *Galileo* reaches Jupiter.

James Hervat is a freelance illustrator and photographer living in Richmond, Kentucky. His work has appeared in *National Geographic*, *World Book Encyclopedia*, *Sky & Telescope* and many other books and scientific journals.

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