The PLANETARY REPORT

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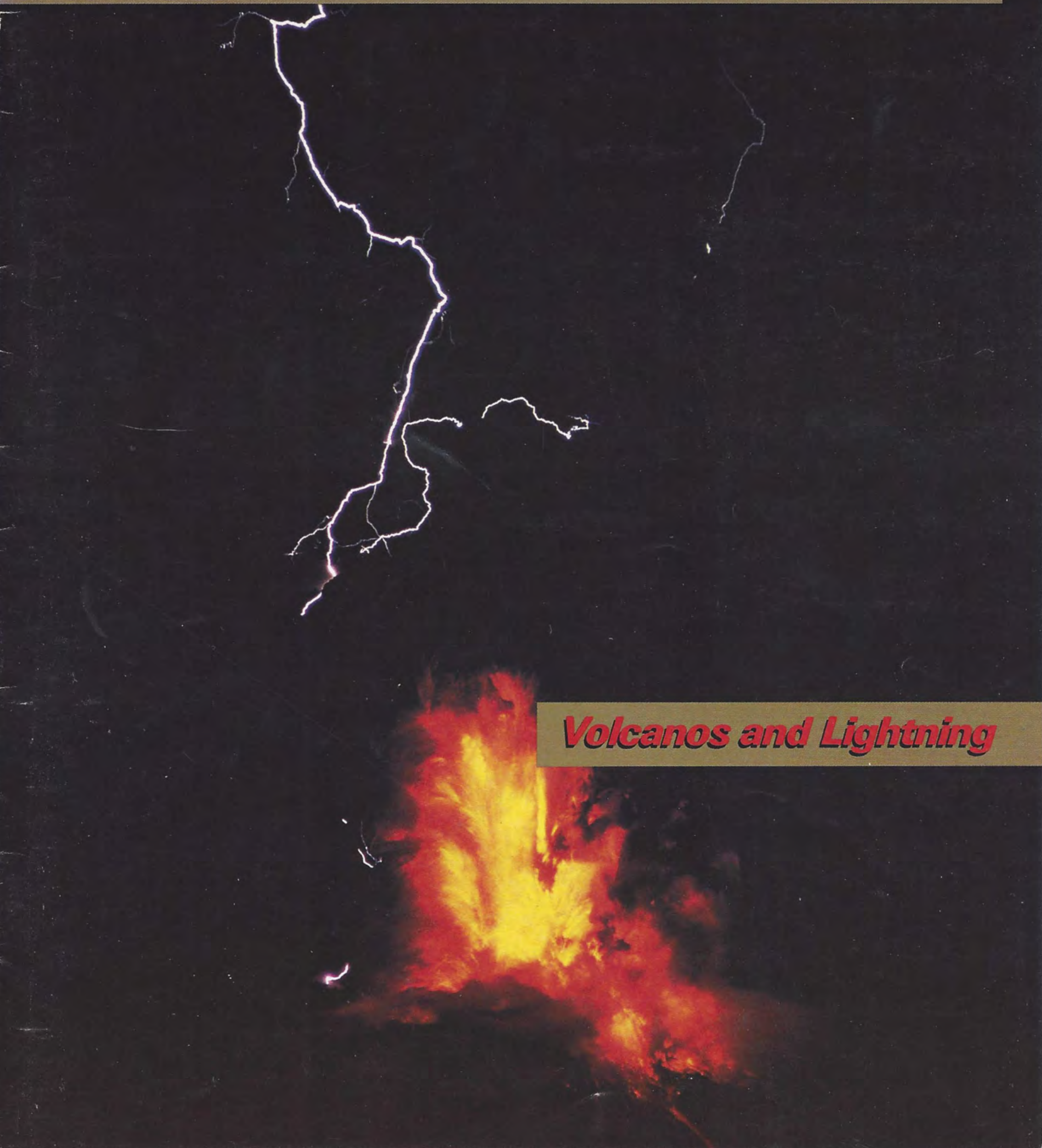

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***COVER:** Lightning strikes during the eruption of the Del Fuego volcano near Antigua, Guatemala. Though the environments of the planets in the solar system may seem vastly different, they are based on common scientific principles. For example, data from experiments on the Soviet Venera 11 and 12 missions indicated that lightning, such as that shown on our cover, is found around possible volcanic mountains of Venus. (See page 8.)*
Photo: Byron Crader/TOM STACK & ASSOCIATES

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 for publication should be short and to the point. Address them to: Letters to the Editor, P.O. Box 91687, Pasadena, CA 91109.

The article "What's a Space Station Good For?" (by Mark Washburn in the July/August 1984 *Planetary Report*) was excellent. However, the United States is only taking a short-range view of the future of space exploration and development. This country should not build a space station yet. Rather, the United States should pursue with full vigor a long-range view in its space program.

We should start taking our long-range view now by returning to the Moon, where we can establish bases and use lunar materials to make space stations in Earth orbit as well as in lunar orbit. This method of building space stations would be much cheaper and more efficient than by sending materials from Earth and assembling them in Earth orbit. Returning to the Moon will enable us to build spaceships that can be sent to the planets and to the stars from our only natural satellite. This method will be cheaper in terms of fuel and money.

The only question I have is what plans does NASA have — if any — of returning to the Moon? The answer to that will tell about our long-range view of space.

WILLIAM HOUGHTON III, *Doylestown, Pennsylvania*

"The decisions we make today will determine the human future in space, not just for the next decade, but for the next century and beyond" (a statement from Washburn's article) sums up all the reasons that a manned space station not only should, but must, be built. It is not only the next logical step in space exploration and humanization, but a foundation upon which large and sophisticated space probes can be constructed and tested.

This is not a question of space exploration or humanization, but rather how can man and machine best complement each other to achieve long term goals in space.

STUART A. HIRSCH, *Randallstown, Maryland*

I read with great interest the recent articles concerning the question of building a space station. One thing which was not stressed was the general direction in which recent NASA activities are heading, and I believe the question should be considered in these broader terms. Since the development of the Space Shuttle, the NASA pendulum has begun to swing away from space exploration and research, and toward an industrial-type research and development program. The recent "Ace Delivery Service" clowning by the Shuttle crews illustrates this point. Do we really want to see our space exploration program evolve into a high-tech delivery service for major aerospace companies? NASA's funding of a space station may result in an even more industrialized mode of operation for the agency.

This does not mean, however, that NASA should stay out of the space station business completely. A station mainly devoted to space science research and exploration would be a more acceptable project for NASA to undertake. If Earth-bound industries want a significant amount of time and resources spent on their projects, they should contribute significantly more to the funding.

The space station question presents us with an opportunity to clarify or even redefine NASA's role in space. In the future, NASA should be but one of several organizations operating above the atmosphere. They should be on the scientific frontier, conceiving and developing new technologies, and then giving the private sector the responsibility for developing their own applications. In this way, NASA would be free to do the exploration and development they are so good at, and the day-to-day operation of a space-based industrial complex would be left to the industrial organizations.

DAN L. WHITTLE, *Rock Rapids, Iowa*

Seeding the Galaxy

The Los Alamos Conference on Interstellar Migrations

by Eric M. Jones and Ben R. Finney

One of science's legends concerns a lunchtime conversation held in Los Alamos shortly after World War II. According to a participant, physicist Edward Teller, several scientists were sitting around the table discussing, among other things, flying saucers and faster-than-light travel. The conversation moved on to more practical matters, but then, suddenly, the great Italian physicist, Enrico Fermi, asked, "Where is everybody?" His companions laughed and all seemed to know that Fermi was still thinking about space travel and extraterrestrial visitors.

In the almost thirty years since that luncheon, we have begun to venture into space. Orbiting space stations, permanent lunar bases and even a martian settlement may be built in the near future. Within the next few centuries our descendants may be ready to journey between the stars, perhaps riding in large interstellar ships loosely patterned on Gerard O'Neill's habitats, propelled by giant sails driven by microwaves. If our descendants spread into the galaxy, they might fill the available niches in a short time — short compared to the age of the galaxy. Considering this, we might restate Fermi's question: Why, if humanity might soon spread across the galaxy, do we see no evidence that extraterrestrials ever crossed interstellar space to visit our solar system?

Today, with growing human activity in space, Fermi's question seems particularly relevant. Although we can now only speculate about extraterrestrials, we do know something about ourselves and how we have responded to past challenges and opportunities. What can we say about prospects for space development? What lessons might we learn from the human experience on Earth?

To this end, we organized the Conference on Interstellar Migrations, held at Los Alamos in 1983. Participants included scholars from space science, anthropology, demography, history, paleontology and astronomy. The discussions covered past human migrations, prospects for human expansion into space and implications for the Search for Extraterrestrial Intelligence (SETI). The conference was sponsored by The Planetary Society, the Los Alamos National Laboratory, the California Space Institute (Calspace) and the School of American Research.

Ancient Migrations

Human migration is very ancient. It began perhaps 5.5 million years ago when an early hominid, *Australopithecus*, took the first "giant leap for mankind" by leaving the sheltering trees of the tropical forest to walk erect on the African savannah. From the beginning, humans have used technology to supply basic needs. *Australopithecus* developed simple tools that enabled them to become the premier food-gatherers of the grasslands. A later species, *Homo habilis*, added stone tools and became hunters as well. However, it was not until about a million years ago that technology had advanced enough for humans (now *Homo erectus*, our immediate ancestor) to leave Africa. With fire and skin clothing, humans spread northward without having to undergo the biological adaptation that often accompanies range expansion by other species.

Despite these successes, *Homo erectus* lacked the technical capability to spread beyond Africa and Eurasia. It took a new species and a new technology to go farther. By 40,000 years ago *Homo sapiens* had arisen; the species crossed the Bering land bridge to the New World and reached Australia and New Guinea using simple watercraft. With a few exceptions, including Antarctica and the islands of the central Pacific, humans then occupied virtually all of the land on Earth.

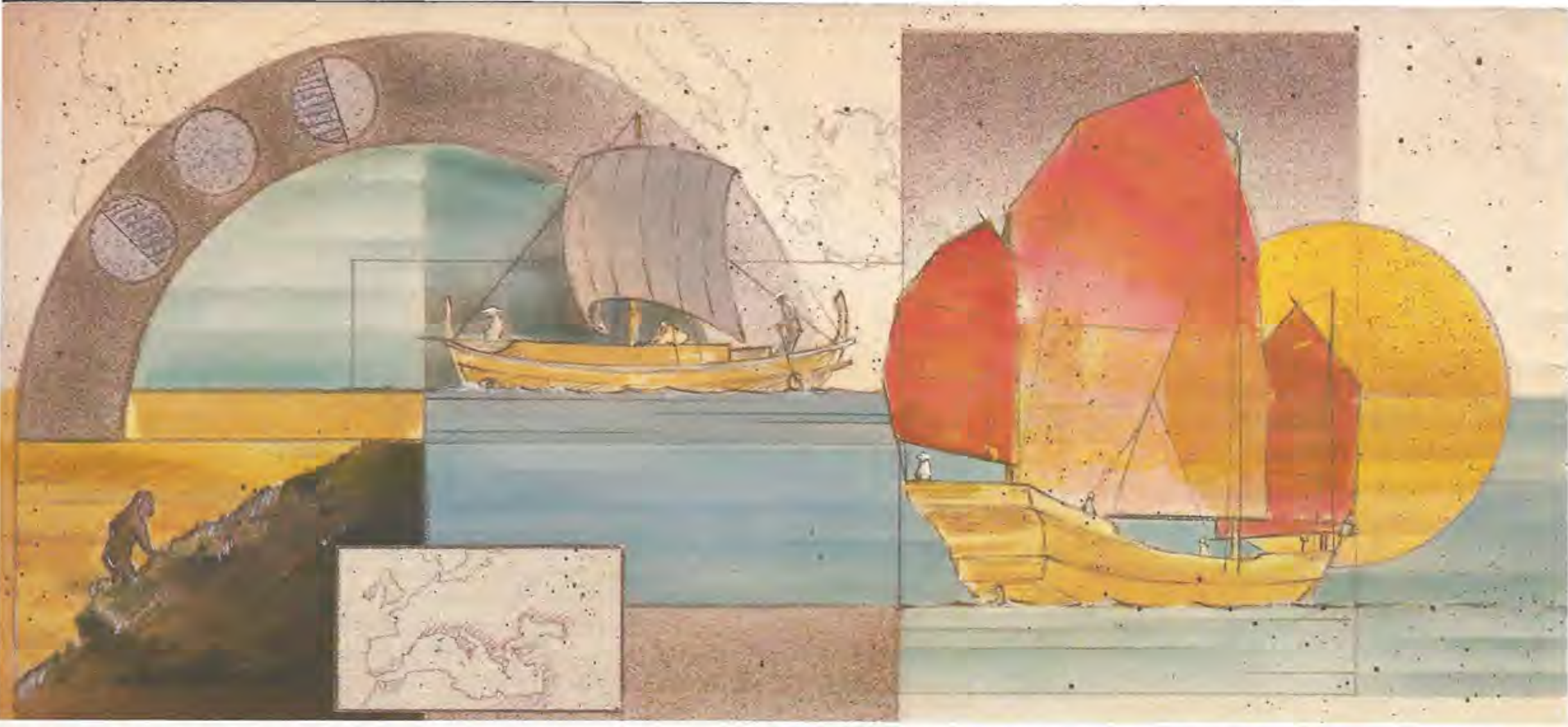
Homo sapiens has clearly been a very successful species. At the Los Alamos meeting, anthropologists Richard Lee of the University of Toronto, Joseph Birdsell of the University of California at Los Angeles and Nancy Tanner of the University of California at Santa Cruz provided insight into the human character. For a very long time, humans lived in hunting and gathering bands. Two living examples are the Australian aborigines and the Kalahari San. In both populations, about 25 men, women and children live together as a band. The bands are loosely clustered in tribes of about 500 people. Membership of the bands changes frequently as individuals move from band to band, but rarely move outside the tribe. Similar structures are repeated even in modern urban communities. Studying these ancient patterns may provide useful guidance when we begin to consider how to design communities in space.

New Technology

About 10,000 years ago, a new element appeared. The advent of agriculture led to villages, towns and cities and a burst of fresh technological innovation. Ben Finney of the University of Hawaii described one such innovation: the development of fast and seaworthy sailing craft that enabled the Polynesians to settle the central Pacific.

This seafaring people appeared in the archaeological record about 2500 B.C. among the islands north of New Guinea. About 1500 B.C. they reached Fiji, Tonga and Samoa, all previously uninhabited. There they paused for a thousand years before suddenly exploding across the Pacific. The founding populations of the various island groups were probably very small, perhaps a few dozen people. But once established, the island populations grew very large. In Hawaii, for instance, the population had grown to a quarter of a million people by the time Captain Cook arrived.

The Polynesians were superb navigators — there is no reason to believe that their colonization voyages were accidental. To set up successful colonies, they had to import seeds and breeding stocks of food plants like breadfruit, coconut, sweet potato and banana. Polynesian success may also have been due to a social structure where rank was largely determined by ancestry. So everyone knew who was in charge on long ocean voyages. →



Frontier Communities

Douglas Schwartz of the School for American Research described a number of frontier communities where success and even survival depended on the settlers' sharing goals and having strong leaders. You may recall the story of the first Virginia Colony, which perished for lack of realistic goals. A community faced with survival in a new environment usually becomes very close-knit; the social structure may become rigid, forcing individualists to seek their fortunes elsewhere. In space, such a pattern might quickly lead to secondary settlements.

In the beginning, human expansion into space will be very expensive, with governments heavily involved. The Los Alamos conferees discussed four large-scale historic expansions: the settlement of the Mediterranean basin by the classical Greeks, the Viking expansion across the north Atlantic, China's brief foray into the Indian Ocean, and the Spanish conquest of the Americas. The Greek, Chinese and Spanish explorers all heavily depended upon institutional support.

Lee reminded us that the Greek city-states established several dozen overseas colonies beginning about 700 B.C. The main aim was trade. Within a few generations, the overseas population exceeded that of Greece itself. However, the great flowering of Greek civilization that followed came mainly at home.

The Greeks confined themselves to the calm waters of the Mediterranean, but the Vikings pushed west into the north Atlantic. In the ninth century, they reached Iceland and created a settlement that flourishes to this day. Farther west in Greenland and Newfoundland, they were eventually defeated by cold, disease and the natives. The lesson: Disaster can strike even the toughest settlers.

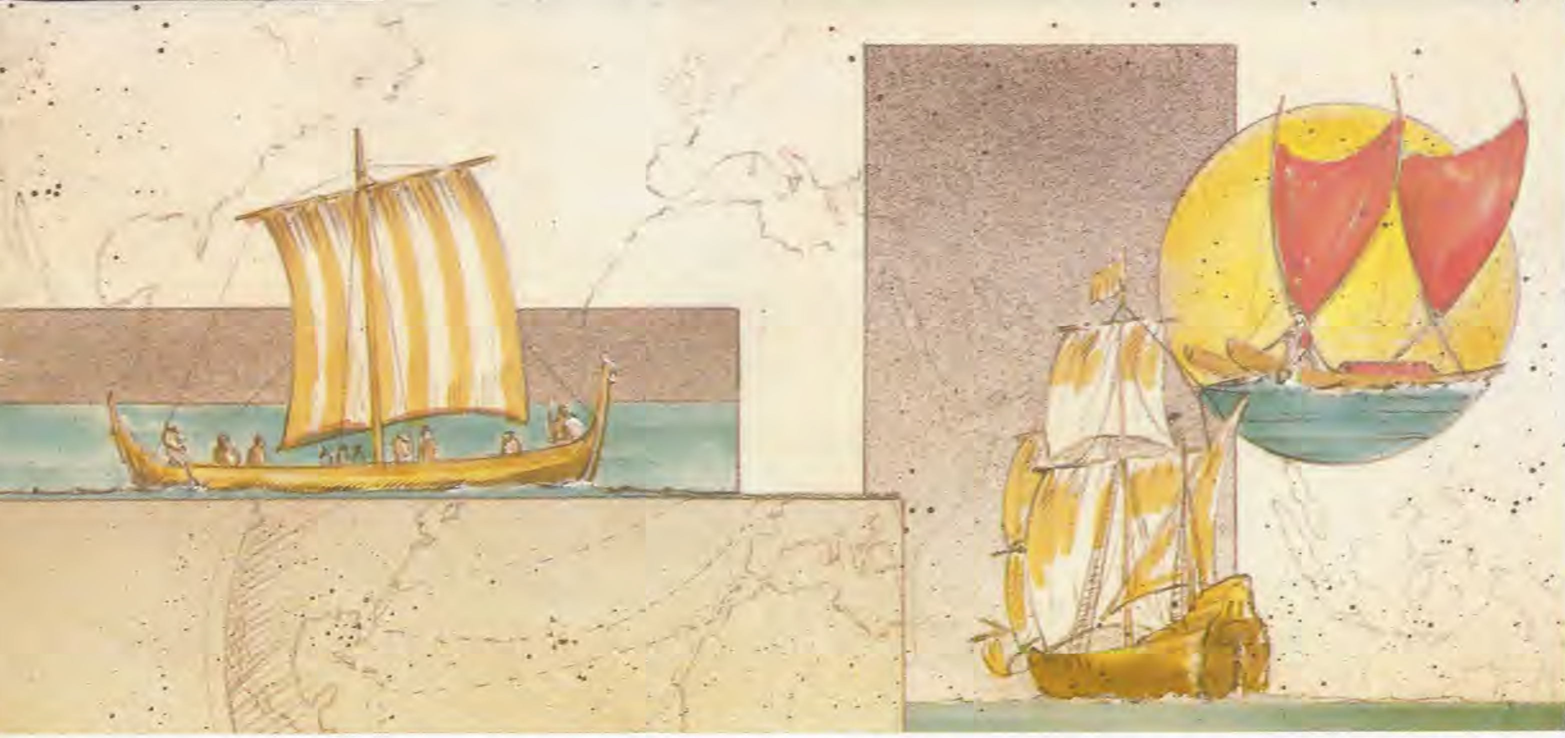
Cautionary Tales

Alfred Crosby of the University of Texas at Austin related two cautionary tales. One was the familiar story of the Spanish conquests in America, but with emphasis on the role of the Spaniards' powerful, unseen ally — disease. Large fractions of the native population died of smallpox and other Old World diseases introduced by the explorers. This story reminds us of the dangers of reuniting separated populations. The period of isolation need not be long. Before stern measures were taken, visitors to Antarctic research stations used to trigger epidemics of flu and colds among the staff. The lessons for space colonists should be obvious.

Crosby also mentioned the voyages of Cheng Ho, the famed eunuch of the Ming Court who commanded seven voyages into the Indian Ocean between 1405 and 1433. The expeditions were made primarily to "show the flag" and ended when, in Crosby's phrase, "on the brink . . . of everything" Chinese bureaucrats called a halt to these "needlessly expensive voyages." How different history might have been if China had continued! We need only consider that the fleets were manned by tens of thousands of Chinese. History might take a similar turn if the United States or the Soviet Union abandoned space exploration; some emerging spacefaring nation could assume the leadership.

If humanity does begin to settle space, how fast might the population grow? Demographer Ken Wachter of the University of California at Berkeley noted that in most frontier societies population growth is rapid. For example, during the first few decades of English settlement in Australia the colony's population grew at eight percent per year. Birdsell noted that small founding communities often grow at very large rates even in harsh environments. He cited several colorful examples of small groups doubling in size every generation. He also discussed the "dangers" of inbreeding. These dangers are well-known to stock breeders, but Birdsell maintained that the dangers are overstated. He thinks that, if a founding population comes from many sources and does not share many "bad" genes, a community as small as 16 people can remain genetically viable indefinitely.

Although many conference participants agreed that population growth would be rapid at the frontier, William Newman of UCLA and Carl Sagan of Cornell University advanced a counterargument. In developed nations population growth is quite low. It is possible, they argue, that the economic advantages of small families will carry over into space. Also, the societies that mount interstellar ventures will, in most cases, be those that have resolved problems such as nuclear war and overpopulation. If the territorial imperative, which Newman and Sagan see as the prime mover of historical expansions, is removed, then popula-



ILLUSTRATIONS: S. A. SMITH

tion growth and expansion might be very slow. With slow expansion, might not evolution change the expanding species so that migration would stop after a few million years? These arguments, although controversial, are central to any discussion of Fermi's question.

Technology and Social Innovation

Tanner noted that technological development is outpacing social response. We may need social innovations if space development is to succeed. In space, we may have the opportunity to try cultural experiments (accidental or planned). Many will fail, but we may increase the rate of success if we consciously include helpful elements. Above all, happy communities tend to be those in which everyone has a role to play, a useful job to do. We ought to think carefully about the relative roles of people and machines in space.

When we go into space, we will depend on technology far more than any of our ancestors did. Space encompasses a vast collection of environments from the surfaces of alien planets to the vacuum of interstellar space. None will have the ready-made support system that Earth provides. Nevertheless, there are resources aplenty if we are willing to adapt to new modes of living.

William Hartmann of the Planetary Science Institute discussed these space resources. We will be able to tap the most economical sources first. Obvious candidates are the Moon, Mars and its tiny satellites, Mercury, the asteroids (especially Earth-crossers) and the jovian satellites. Development of these resources is expected to combine a mix of planetary settlement and construction of orbital habitats.

David Brin of Calspace described some of the things one can do with the Space Shuttle's external fuel tank to get things started. Dave Criswell, also of Calspace, discussed using lunar and asteroidal materials to fuel rapid economic growth in the Earth-Moon system. Eric Jones of the Los Alamos National Laboratory suggested that we might adapt lunar technology (such as Gerard O'Neill's electromagnetic driver) to Mercury, and build gigantic power stations in close orbit about the Sun.

Sustaining Growth

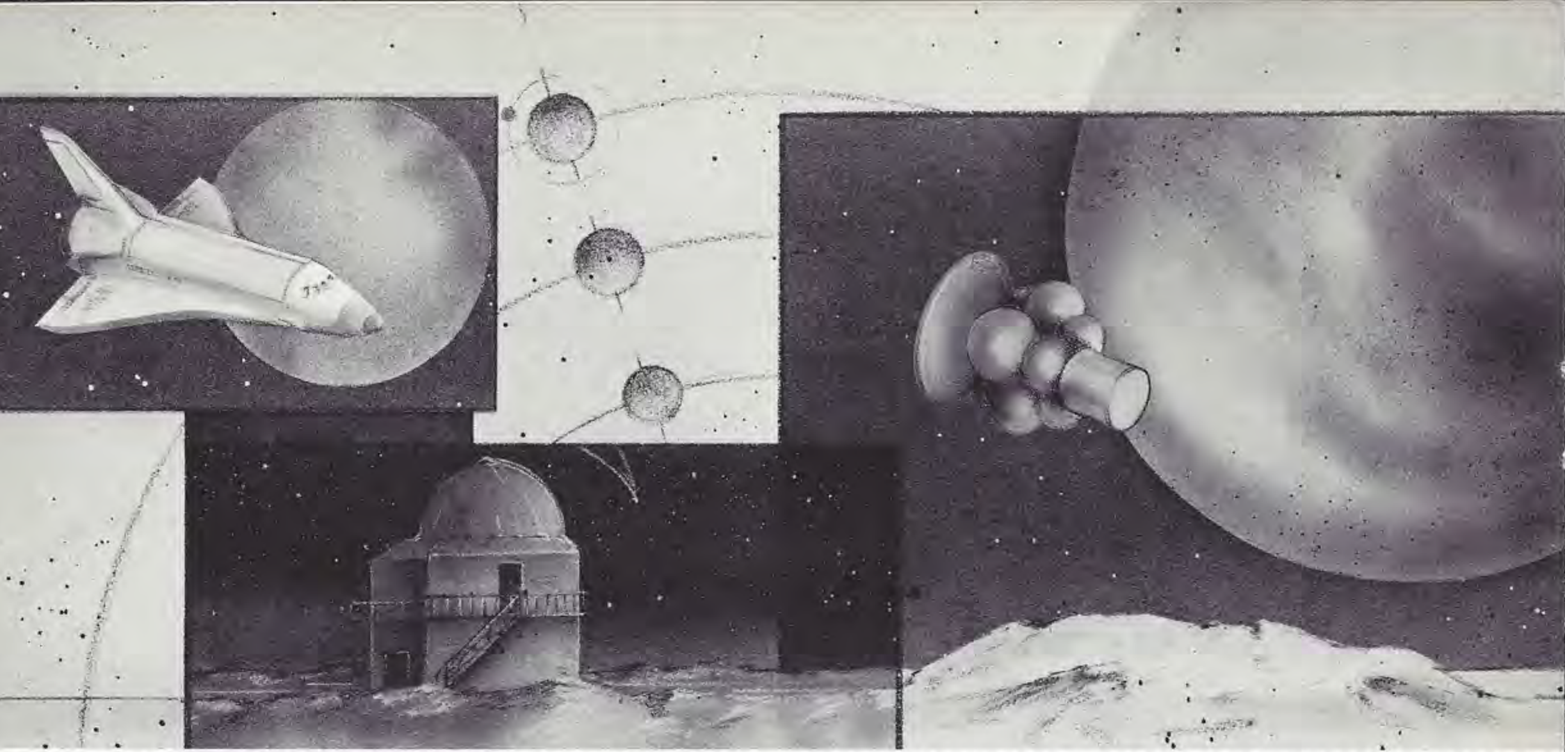
Criswell argued that economic growth of nearly 20 percent per year could be sustained in space. If such a trend were to continue (and some of us were a bit skeptical), by the middle of the 21st century the asteroids would have been consumed. Even if this happens much later than Criswell imagines, humanity would eventually have to face the reality that solar system resources are limited. Although interstellar migration might provide humanity with a new frontier, no migration has ever solved the basic problem of limited resources at home. Interstellar distances are so great that the solar system must be considered as a closed economic system. The only lively trade is likely to be in information. Criswell suggested, however, that the bounds of solar system development will not be reached until we have begun to tap the material resources of our star. The great solar furnace produces not only energy, but processed materials! He outlined a scheme for mining the Sun, and in the process greatly increasing the expected life space around our star.

Taking the Sun apart! Who knows what things our descendants will try as they learn to cope with living in the solar system. But in a sense, the future of humanity may no more be determined by what we do in the solar system than by what any one group of our ancestors did in the past. Our success as a species has come more from our cultural and technological inventiveness than from our physical abilities. And that means diversity.

Some species, such as the ancient cockroach, have survived for a very long time because their very simple lifestyles and rugged construction made them impervious to change in the world around them. Humans thrive on diversity; in the solar system, as on Earth today, there will be less room for cultural experiment as the centuries pass. Only as we go to the stars will there be real room for diversity. There is a useful analogy from the history of life on Earth.

Transforming Life

James Valentine of the University of California at Santa Barbara described the Cambrian revolution that transformed terrestrial life. Up until about 500 million years ago Earth was dominated by simple life forms. Then something dramatic happened. In perhaps no more than a few million years, a bewildering variety of new forms of life appeared. We now know that dramatic changes in form can follow from small changes in regulatory genes. Perhaps the Cambrian revolution represents a dramatic development in the regulatory system. We do not know. But space travel may



permit a new burst of evolution. As our descendants leave the solar system, they will encounter fresh challenges. Many of the communities may be small, an ideal setting for both cultural and biological evolution.

We outlined two general paths that our descendants may take to the stars. One is the traditional route of science fiction: pioneers going from star to star in extremely fast ships. These interstellar journeys might take several generations to complete. There are hundreds of billions of stars in the galaxy and hence, hundreds of billions of possible biological and cultural experiments. However, the space around each star may be as rich an oasis as is our solar system. The potential for population growth might be equally large. As with very large animal populations on Earth, diversity may not be prevalent within a thickly populated stellar oasis. However, there is another road to the stars.

We have argued that interstellar space is liberally sprinkled with interstellar comets, each of which could support populations of several hundred with starlight gathered by gigantic mirrors built of cometary aluminum. Such an environment might provide an opportunity for humanity to return to our "natural" lifestyle — the small, self-sufficient communities of our hunting and gathering past. If this should happen, we might see rapid speciation of genus *Homo* and an explosion of cultural experiments.

Who Will Go?

Whenever the subject of space development and interstellar migration comes up, someone asks, "Who would want to go?" Right now there are plenty of volunteers for space missions; but when we contemplate fast-ship journeys covering a lifetime or a drifting voyage on an interstellar comet that would commit generations to the interstellar deep, the question becomes larger.

The simplistic answer is that countless men and women have committed themselves and their descendants to new lives. However, it is a question deserving a longer look. Philosopher Edward Regis of Howard University asked the question this way: Are there circumstances under which it is morally impermissible for parents to bear and raise children? No one at the conference argued with his contention that a Nazi concentration camp was such a place. But what about an interstellar ark in which generations are confined to a small space and denied the beauties and opportunities of Earth? The sense of his answer was this: None of us is guaranteed right of access to all the beauties and riches of the universe. For example, uncounted individuals and generations have never seen the Grand Canyon. Each child is given a world not of his or her own choosing. But what defines morally intolerable situations is the inability of each individual to have a measure of control over his or her destiny — not necessarily in the physical environment, but certainly in the possibility of choice. An interstellar ark may be confining, but it would not, we would hope, be an emotional prison.

Choices and Challenges

The conference left us with a feeling that, while space development offers humanity some difficult choices and great challenges, it will not require great changes in human character. We have used technology in the past to settle strange new terrestrial environments and, on the whole, this expansion of human capabilities has enriched our lives. So it may enrich the lives of those who go into space. Although a few saints may go to the stars (along with the inevitable villains), the vast majority will be ordinary people.

Jill Tarter of the NASA Ames Research Center and U.C. Berkeley ended our discussions with a survey of the Search for Extraterrestrial Intelligence (SETI). It makes looking for the proverbial needle-in-a-haystack seem easy. Perhaps if interstellar migrations do occur, we might hope to detect signs of large-scale activities. Our efforts to date have been very small, covering only a tiny number of stars listened to for very short times and in pitifully narrow wavelength regions. However, the recent revivial of the SETI program, including The Planetary Society's Project Sentinel, offers the chance that we can begin a broader and more concentrated search.

We began this report with Fermi's question: If humanity can go to the stars, why haven't beings born under other suns reached the solar system? We will not be able to answer Fermi's question until humanity either goes to the stars or succeeds in its search for communications from extraterrestrials. It is an experimental question.

Eric Jones is a Laboratory Fellow at the Los Alamos National Laboratory. Ben Finney is a Professor in the Department of Anthropology, University of Hawaii, Honolulu.

DUST DISK Discovered Orbiting Star

***I**n the last issue of* The Planetary Report *we focused on the possibility of planetary systems forming around other stars. While that issue was in the mail, two scientists announced their optical discovery of a disk of solid material orbiting a nearby star. Here we discuss this important new step in the search for extra-solar planets.*

For the first time, scientists on Earth have observed and photographed a "dust disk" of solid particles orbiting a star other than our Sun. The star is Beta Pictoris, which is about 50 light years from Earth. Astronomers Bradford A. Smith of the University of Arizona, and Richard J. Terrile of the Jet Propulsion Laboratory (JPL) in Pasadena made the discovery.

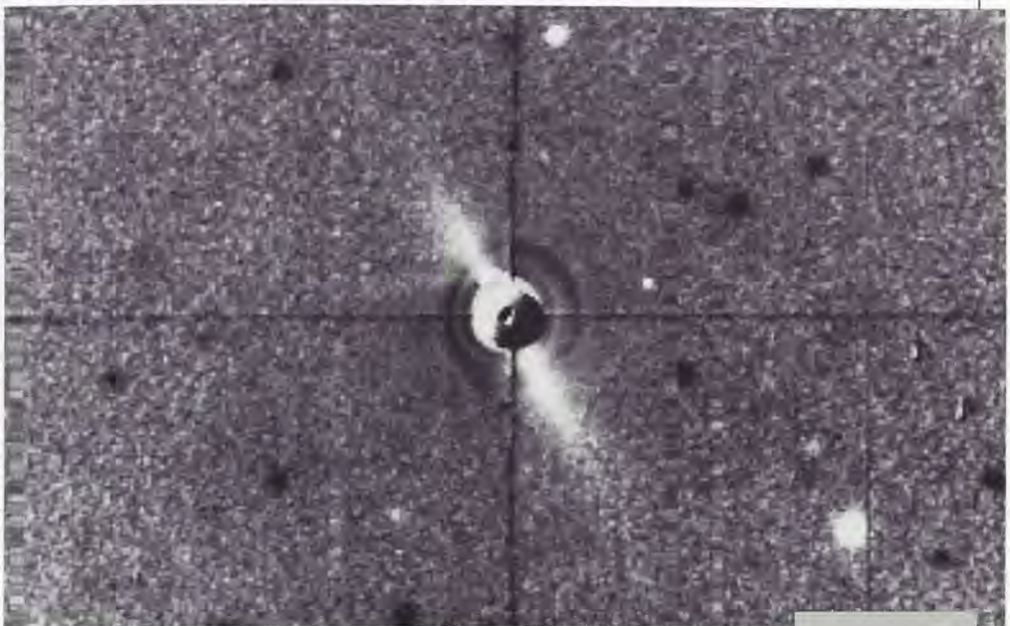
Dr. Terrile believes the significance of the discovery is two-fold. "Scientifically, it indicates that we will be finding more solar systems, in different stages of development," he said. "Scientists have studied the life-cycle of stars, and now they will be able to study how solar systems form and evolve."

The second significant aspect of the discovery, according to Terrile, is philosophical. "The question has always been 'Are we alone?' in a fundamental quest to find other life in the universe," he said. "A corollary question is 'Are there other solar systems?' The answer to that question helps to answer the first question."

There is some speculation that planets may orbit Beta Pictoris inside the dust disk, although no direct images of such planets have been made. The evidence suggesting that planets might be a part of the system is both theoretical and observational. Theoretically, planets form from flat disks like the one around Beta Pictoris. Our solar system is flat.

The observational evidence, though weak, suggests that planets might be a part of the system. According to Dr. Terrile, measurements of the brightness of the outer part of the disk indicate that the density of material increases toward the star. However, if the density of the material were to continue to increase near the center of the disk, then the light from Beta Pictoris would be much fainter than what is observed. An area about the size of our solar system around Beta Pictoris appears to have been depleted of material. What could have cleared out this area around the star? A possible answer, according to Dr. Terrile, is that there may be a compact system of planets in that area.

Commenting on the discovery, David Black, theoretical astrophysicist at NASA Ames Research Center and guest technical editor of the *Planetary Report's* extra-solar planets issue (September/October 1984), said: "It's the kind of result that stimulates further research. People are starting to focus on the question of planets around other stars, and are looking for all stages of disks to find planets. There still is essential data that we need in order to understand the solar system. We must find and characterize the condensed objects – the planets – themselves."



This computer-enhanced CCD (charge-coupled device) electronic image of the star Beta Pictoris shows a circumstellar disk extending sixty billion kilometers. The special camera and the image processing blocked the glare of the star, enabling the faint disk to be seen.
Photo: University of Arizona and Jet Propulsion Laboratory

The astronomers got the clue that Beta Pictoris might be a good place to look for a planetary system from IRAS (Infrared Astronomical Satellite). According to reports from the IRAS science team, Beta Pictoris and three other stars gave off an unusually large amount of infrared radiation, which indicates material orbiting a star.

From Earth, the disk around Beta Pictoris is seen edge-on, extending more than 60 billion kilometers (40 million miles). The flattened shape of the disk indicates its young age of a few hundred million years. (By comparison, our solar system is 4.5 *billion* years old.) If the disk were older, it would not be as flat because orbiting planets would have disturbed the particles, and some of the debris would have been ejected into interstellar space.

Scientists think the circumstellar disk is composed of innumerable particles that range in size from microscopic to a few miles across. The best guess is that they are made of ices, silicates and organic compounds. Earth and other planets of our solar system probably were formed from these same materials.

Beta Pictoris is twice as massive as our Sun, and is intrinsically ten times brighter. We see it from Earth as a faint star in the constellation Pictor, visible from the Southern Hemisphere.

The astronomers made their observations at the Las Campanas Observatory in Chile. An optical instrument called a coronograph was attached to the telescope because it finds very faint objects close to bright ones. A CCD (charge-coupled device) electronic camera recorded the image, which was then computer-processed at JPL and the University of Arizona.

Drs. Terrile and Smith will continue to investigate the Beta Pictoris system, and will also survey the sky in both Northern and Southern Hemispheres for other planetary systems. Dr. Terrile feels certain that when observations can be made above the Earth's atmosphere there will be exciting results. Instruments specifically designed for finding and imaging planets are on the drawing board. "In the next five years, we will be imaging planets around other stars," he said. □

— Lyndine McAfee

Lightning, Clouds and Volcanos

Searching for Lightning on Venus

Venus, the brilliant planet that shines in our morning or evening skies, is gradually revealing the mysteries that lie beneath her perennial veil of clouds. American and Soviet spacecraft, and observations by ingenious planetary astronomers based on Earth, are elucidating the nature of the planet and its deep, dense, carbon dioxide atmosphere. In 1962 Mariner 2 *indicated that the planet's surface temperature is well over 450 degrees Celsius. (See the November/December 1982* Planetary Report.*) Since then a series of Soviet* Venera *and United States* Mariner *and* Pioneer *spacecraft have yielded more knowledge of the planet as a whole and also detailed observations at a few spots on its surface. Today, almost the entire surface has been mapped at low resolution by the radar altimeter on the* Pioneer Venus *Orbiter, and that mission is continuing to explore the surroundings of the planet. Two Soviet orbiters,* Venera 15 *and* 16, *are now taking the next step by mapping part of the northern hemisphere in more detail by radar.*

In the accompanying article, Leonid V. Ksanfomaliti tells us how one part of the planet's remarkable story is unfolding: We now have evidence that enormous volcanic eruptions are probably occurring on Venus.

by Leonid V. Ksanfomaliti

The search for lightning in the clouds of Venus has led to an unanticipated finding: The electrical discharges detected by spacecraft appear to have no connection with the cloud layers. Recent observations indicate that enormous volcanic eruptions, accompanied by lightning discharges, are taking place on the surface of Venus.

Our story begins with some new experiments undertaken by the Soviet *Venera* and the United States' *Pioneer* Venus spacecraft.

In 1976 preparation for the flight of *Veneras 11* and *12* was at full speed when a new idea arose: Why not complete the scientific payload new instrument to look for lightn Venus' atmosphere? At that time, was the only planet on which ligh was known. (The *Voyager* spac have since detected lightning o Jupiter and Saturn.) During thu storms, nitrogen oxides, ozone even hydrogen cyanide are pro and these compounds play an i tant role in atmospheric physic chemistry on our planet. Perha production of some known trace tuents in Venus' atmosphere co explained by the same mechani

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imagine what it was like to add a new instrument to a half-ready flight payload. It was necessary to find additional telemetry channels, free connectors and a place to mount the instrument. We had to revalidate tests already done. It was a very difficult and somewhat risky enterprise which had to be completed in a very short time.

Hunting for Lightning

To hunt for lightning we decided to use a miniature, specially built, super-long-wavelength radio receiver. In this waveband, "crackles" from earthly lightning have their greatest strength.

(continued on next page)

The physical processes that produce lightning in earthly thunderstorms are still not well understood, but they are probably the same processes that generate the lightning in volcanic clouds on both Earth and Venus. High-speed convective air currents carry particles upward, where they are ionized (electrons are removed) and somehow separated according to size. This sets the stage for the electrical discharge of lightning. On Earth, the cloud particles are water droplets and water ice; on Venus, they are probably sulfuric acid droplets. The temperatures within terrestrial thunderstorms are cold, between −10 and −20 degrees Celsius. In volcanic clouds on Earth, and on broiling-hot Venus, the clouds are warmer. It will take more study, both here and on Venus, before we completely understand how these spectacular and powerful displays are produced.

ABOVE: This electrical discharge lights up the clouds of a New Mexico thunderstorm.
Photo: L. Brown/The Image Bank

LEFT: Lightning strikes during the September 12, 1978 eruption of Usu volcano in Hokkaido, Japan.
Photo: M. Kotake

BACKGROUND: The eruption of El Chichón volcano in Mexico, April 3, 1982, produced this spectacular electrical display.
Photo: Servando De la Cruz-Reyna, Instituto de Geofísica, National University of Mexico (UNAM)

***ABOVE:* A lightning bolt strikes during the May 18, 1980 eruption of Mount St. Helens in the northwestern US.**
Photo: Donald A. Swanson, David A. Johnston Cascade Volcano Observatory, US Geological Survey

***ABOVE LEFT:* This Pioneer Venus orbiter altimetry map of Venus' topography shows the mountainous regions of Beta, Phoebe and Atla Regios. Lightning discharges were found to coincide with activity at these probably volcanic sites.**
Map: US Geological Survey

As we had no information about Venus lightning, the Groza ("Groza" is the Russian word for thunderstorm) instrument was designed with the highest possible sensitivity. One particularly difficult problem was interference from other electrical systems onboard the spacecraft. The instrument also had to operate normally at temperatures over 475 degrees Celsius and at a pressure of 100 atmospheres.

During this same time, the *Pioneer* Venus orbiter was being prepared for flight. Its payload included an electric-field detector intended for plasma investigations. This instrument operated in a frequency range that partly overlapped the Groza bandwidth. Before the two experiments began, their authors worked quite independently.

In December 1978 *Pioneer* Venus and *Veneras 11* and *12* arrived at Venus to make their investigations. During the *Venera* probes' descent through the atmosphere, Groza registered many thousands of impulses similar to those produced by earthly thunderstorms, but the impulses were much more frequent. We noted at once that some of the sources were surprisingly localized and one source of radio noise was observed by the instruments as a point with a field-strength that varied periodically during some minutes. This was very unlike a terrestrial thunderstorm. But it took a long time to understand what was causing this effect.

Some days later the *Pioneer* Venus instrument also received impulses with the characteristic signature of lightning. Orbiting above Venus' atmosphere, *Pioneer* picked up discharges propagating along magnetic field lines. Although it did not record as many impulses as the *Veneras* did, there was one advantage to the *Pioneer* experiment: The impulses could be associated with the planet's topography.

The Electrical Dragon

The discharges in Earth's storm clouds are not closely tied to topography, but they do exhibit a concentration in the equatorial zone. The Venus lightning discharges behaved differently. Venus' clouds lie between altitudes of 47-70 kilometers, and the mass and quantity of cloud particles are sufficient to accumulate large electrical charges. In principle, the clouds could be a source of lightning. But analyses of the data indicated instead that the discharges took place in the lower cloudless layer of the atmosphere, or even on the surface of the planet. The experimenters expressed their perplexity in the unscientific name of their scientific paper: "The Electrical Dragon on Venus."

Could these electrical discharges be caused by erupting volcanos? As nothing was known about volcanos on Venus, the suggestion was a timid one. However, radar images showed possible volcanic constructs, especially in the Phoebe region where *Veneras 11* and *12* landed in 1978. *Veneras 13* and *14* joined them there in 1982.

The idea about volcanism on Venus began to grow. However, new data were needed to test the hypothesis. They soon came from the *Pioneer* Venus orbiter.

The orbiter continued to observe

impulses. They were compared with magnetometer data and were displayed on a map of the planet's surface as places were the discharges occurred. When sporadic events were eliminated, the remaining events produced a pattern that was hard to believe: Tens of discharges overlapped at the same points on the map, at the same sites that morphologists pointed out as possible volcanic regions, such as Beta, Phoebe and Atla Regios. The *Pioneer* Venus measurements did not cover the entire planet, but the concentration of discharges at the same sites was very interesting and almost excluded their explanation by weather phenomena.

The hypothesis that volcanos erupt on Venus may appear to conflict with the observation that the lower atmosphere is not very dusty. But we note that, first, not all of Earth's volcanos throw up great amounts of dust; and second, because of the high density of Venus' atmosphere, volcanic plumes above eruption sites should be much smaller than those on Earth.

More Evidence

Let's now turn to an observation that seems far from the problem we have been considering. Ground-based polarimetric measurements (using the properties of sunlight reflected off the Venus cloud tops) made in 1969-72 revealed the sizes of the droplets making up Venus' clouds: They had a mean diameter of two micrometers (a micrometer is a thousandth of a millimeter). Many investigators repeated these measurements and established the particle size and also the refractive index, 1.44. This index led to the conclusion that the clouds are composed of concentrated sulfuric acid. (Droplets of sulfuric acid slow or bend light by just the right amount to give the observed refractive index.)

But in 1978-79 the polarimetry from *Pioneer* Venus showed the presence of a relatively thick, global haze layer above the clouds. It was impossible not to notice this haze using ground-based polarimetry. By examining records and making new observations, it was indeed found. The haze had appeared and began to spread as early as 1977 and reached its maximum in the winter of 1978-79. The haze was made of the same material as the clouds: It was concentrated sulfuric acid. But the mean size of the particles was four or five times smaller. (In examining older records, it was found that a similar phenomenon had been observed in 1959.) Models of Venus' clouds had to be changed, and physicists looked for a mechanism to provide two sets of sizes for particles of the same material. But by the end of 1979, the density of the haze decreased dramatically, and a year later its density in some regions had diminished five-fold. The haze disappeared under the very eyes of the investigators.

Spectral Signature

One more event accompanied the adventure of the clouds. Sulfur dioxide had been sought in Venus' atmosphere for a long time. It is formed by the energy of sunlight in the very upper cloud layer, and then with a small amount of water vapor, it produces sulfuric acid. Although sulfuric acid had been discovered, all attempts to find sulfur dioxide had failed. Suddenly in 1978-79, different groups of scientists simultaneously and independently found its spectral signature. Probably there had been a sudden enrichment of sulfur dioxide in the visible portion of the atmosphere. Then the sulfur dioxide concentration decayed gradually. Five years later it was less than a tenth as abundant.

The most probable, although indirect, reason for the sudden enrichment of sulfur dioxide is volcanic eruption. Volcanic gases, even from an enormous eruption, cannot change the concentration of sulfur dioxide in the entire atmosphere in just a few years. It would take millions of years. But there is another mechanism that is much more effective. The atmosphere above the volcano is heated and creates a strong convection that delivers a great amount of sulfur dioxide to the upper clouds from the middle troposphere, where the sulfur dioxide concentration is a hundred to a thousand times higher. Calculations showed that just a few volcanos like those in Hawaii could produce this effect over several months.

Gigantic Scale

The scale of Venus volcanism could be gigantic. On Earth, heat from the planet's interior is transported preferentially to rift zones, primarily the mid-oceanic ridges. But on Venus, where no rift zones of global size have been found, the heat has to have certain discrete places to emerge. (Without such local heat outlets, Venus' crust would melt and would not be able to support the known topographic relief of the planet.) Thus Venus may have a small number of hot spots with tremendous volcanic eruptions and many more electrical discharges than those above erupting terrestrial volcanos.

In 1982, the measurements of the Groza 2 instrument on *Veneras 13* and *14* apparently showed a decrease of electrical (and volcanic?) activity, which was accompanied by the disappearance of the small-particle haze and a lowering of the sulfur dioxide concentration in the upper atmosphere.

Veneras 13 and *14* chemically analyzed the composition of surface rocks at their landing sites. The surface composition is very much like a rare type of volcanic rock on Earth. But there is also a difference: A large amount of sulfur is present in the soil. This result shows that sulfur takes part in chemical weathering on Venus and is chemically bound into the surface rocks. It means that, for the sulfur cycle to continue, sulfur must be injected into the atmosphere from volcanos. Otherwise, over geologic time, all atmospheric sulfur, now observed as sulfur dioxide and sulfuric acid, would have ended up in surface rocks.

How soon can we expect a new burst of volcanic activity? The close interaction among different natural events on Venus apparently gives ground-based astronomers a good opportunity to monitor volcanic eruptions using systematic polarimetric measurements of Venus' clouds. Simultaneous spectrometric searches for sulfur dioxide would also be useful tests for such activity. These data will provide a valuable background for future spacecraft observations of our actively evolving neighbor planet Venus.

Leonid V. Ksanfomaliti is a Division Leader at the Institute for Cosmic Research, Academy of Sciences of the USSR. He holds a doctorate in Physical and Mathematical Sciences, and is the author of popular articles as well as scientific papers. He has been responsible for experiments on many Soviet missions to Venus and Mars.

IMAGES FROM THE VENERA ORBITERS

Released exclusively to *The Planetary Report*, these pictures of the surface of Venus were taken by the Soviet Union's *Venera 15* and *16* spacecraft now orbiting that planet. These highly detailed images are proving very valuable to US scientists planning the Venus Radar Mapper mission, and are supplied through data exchange programs between Soviet and US planetary scientists. They are printed here with the permission of the USSR Academy of Sciences.

The banded appearance of the images results from the piecing together of different orbital swaths taken by the radar. The resolution, or limit to perceivable detail, is about 1.25 kilometers. The radar survey has now covered much of the northern hemisphere of Venus. The US Venus Radar Mapper, scheduled to go into orbit about Venus in 1988, will provide additional detail and will complete the mapping of the planet.

We thank Harold Masursky and Stephen Saunders for their help.

Professor V. Barsukov, Director of the Vernadsky Institute of the USSR Academy of Sciences, describes this region as "islands of rather ancient, imbricated terrain within the volcanic plain." Surrounded by the young lava-flow plain called Sedna Planitia, older rocks stick out through overlapping (imbricated) faults. This smooth lava plain has also been seen with the Arecibo radar and resembles the maria regions of the Moon and the northern plains of Mars.

The image covers a region 800 by 1200 kilometers and is centered on 40 degrees north latitude, 0 degrees east longitude.

BY RADAR

This image covers "part of the large zone of tectonic dislocations, formed in the southern part of Ishtar Terra," according to Professor Barsukov. The upper, cross-hatched region is termed "parquet" for its apparent similarity to parquet floors. The feature is also known as tesserae, *Latin for "tiles." Similar rectilinear patterns have been seen on Mars.*

The surface area here is 600 by 900 kilometers and is centered at 53 degrees north latitude, 55 degrees east longitude.

"This terrain resembles folding zones on Earth and was formed as the result of intensive tectonic folding and imbrication," Professor Barsukov said. This area within Ishtar Terra, a massive highland region in Venus' northern hemisphere, is reminiscent of orbital views of Earth's Appalachian Mountains. Ridges and valleys appear throughout the region, formed by tectonic processes and unchanged by erosion. Such features give scientists an opportunity to study the unmodified results of tectonic processes.

From the Pioneer *Venus Orbiter we know that this area exhibits enormous relief, comparable to the region where the western Andes Mountains meet the Pacific Ocean. In the upper right corner is the edge of the north polar region of Venus. This image covers an area 600 by 850 kilometers centered at 70 degrees north latitude, 32 degrees east longitude.*

News & Reviews

by Clark R. Chapman

My habit in this column is to guide *Planetary Report* readers toward supplementary reading in current popular magazines. Occasionally new books capture my attention. I have even been known to describe new results from scientific meetings, or to elaborate on findings published in that great tree-consuming, soft-cover mass of paper known as the "gray scientific literature." This column will be a bit of a departure, but it's back in the familiar territory of the popular magazine. I hope to give you a feeling for a whole magazine by leafing through the pages of a single issue. My subject is the September 1984 issue of that venerable magazine of popular astronomy, *Sky & Telescope*.

This issue has several feature articles of the sort I usually review in this column. A tutorial on comets and cosmic dust by Roger Knacke is a prime example. Well illustrated, the article starts with a traditional summary of what a comet is. It avoids mucking around too long in cometary orbits and comet tails, and soon homes in on the topics that motivate our modern interest in comets: their clues to the origin of the solar system and to relationships between our planetary system and the cosmos. Knacke discusses the probable cometary origin of microscopic Brownlee particles collected in Earth's upper atmosphere. Along with many of us, he most eagerly awaits the impending return of Halley's Comet and the close-up studies planned by spacecraft from several nations.

Knacke's article is only the longest of several items about comets. Two illustrated "News Notes" treat us to some modern findings with historical roots. One reports the discovery of an ancient Chinese archive of comet drawings that seems to be an atlas of cometary shapes circa 168 B.C. The second describes a reanalysis of 1910 photographs of Halley's Comet, taken with the Mount Wilson 60-inch telescope, only recently subjected to modern image-processing techniques. And there is a continuing installment of the "Comet Digest," which maintains a running discussion for amateur astronomers of comets currently visible in the sky.

The amateur astronomer has always been a key focus for *Sky & Telescope* articles and columns. Along with the traditional monthly star maps and planet-finding charts, *Sky & Telescope* is increasing the number of other specialized maps, tables and graphs that help the amateur astronomer find an elusive star or planet in his or her telescope.

I was pleased to see a short article on how amateur astronomers can observe the planet Mercury, which is difficult to see and study because of its proximity to the Sun. A sharp-eyed observer can still "beat the seeing" and avoid atmospheric fuzzing-out of the surface markings on Mercury's quarter-phase disk, just by gazing at the planet through a small telescope when the sky is deep blue and the air relatively still. (Large, professional telescopes are hardly ever turned toward Mercury.) Still, I was a bit horrified by Alan MacRobert's suggestion to find Mercury by off-setting a backyard telescope from the blinding Sun. All of *Sky & Telescope's* warning notes aside, I still think *something* could easily melt or catch on fire if a telescope was pointed at the Sun. It would be far better to line up the telescope on a star in the same position in the dark sky that the small planet will be several hours later when the Sun is up and the sky is bright.

Our lovely Moon is out of the limelight now, fifteen years after *Apollo*. But the September *Sky & Telescope* is cognizant of both its continuing fascination for owners of small telescopes (a guided tour of some interesting lunar features is provided) and also the continuing importance of lunar sample research. As one short article explains, it is rather ironic that the once-neglected field of meteoritics, including the collection of fallen meteorites around the world, is beginning to yield its own treasure-house of information about the Moon. Following last year's headline-making discovery that a particular meteorite found in Antarctica is, in fact, a piece of the Moon, two more meteorites in the Japanese Antarctic collection appear to be pieces of the Moon as well. Moreover, some theoretical calculations by Arizona geophysicist Jay Melosh seem to explain the perplexing fact that these free lunar samples are nearly perfect, hardly damaged at all by their explosive excavation from the Moon during a large cratering impact.

The editors of *Sky & Telescope* have a long sense of history. Through the years, Joseph Ashbrook — editor of *Sky & Telescope* until his death — wrote a column called "Astronomical Scrapbook," usually filled with anecdotes gleaned from the history of astronomy. I, for one, will welcome the publication of many of these columns in book form, which is promised for late 1984. An historical sense lives on at *Sky & Telescope*. For example, we are treated to further speculation about the mysterious and ancient Nazca lines in the South American desert.

Most fascinating to me was Dorrit Hoffleit's thoughtful and personal review of Cecilia Payne-Gaposchkin's autobiography. When Professor Payne-Gaposchkin advised me on my student term paper a couple of decades ago, she was the epitome of the successful woman scientist. The book review reveals, however, that even her stellar career was partly eclipsed by discriminatory actions taken long ago by the powers-that-were in Harvard College Observatory. In another book review, George S. Mumford waxes enthusiastic about Jay Pasachoff's rewrite of Donald Menzel's popular astronomical field guide.

There are many other features in *Sky & Telescope* for the amateur telescope maker or instrument builder, for the rocket enthusiast, for the armchair scientist, and for practically anyone interested in space science. The magazine now sports a new column on astronomical computing; the September issue gives a program for calculating maximum hours of sunlight between two dates. And the interview format is used for introducing us to Roald Sagdeev, who is the Director of the Soviet Institute for Cosmic Research. Academician Sagdeev (a member of The Planetary Society's Board of Advisors) is usually forthright with Western scientists. In the *Sky & Telescope* issue, he promised to let us know when the ambitious Soviet mission to the martian moon Phobos is officially approved.

Clark Chapman is enjoying a sabbatical at the Institute for Astronomy in Honolulu, where he is doing a little research on Jupiter, reflecting and writing, and taking an occasional side-trip to Mauna Kea Observatory to study comets.

SOCIETY NOTES

HUMANS TO MARS

The Planetary Society's Mars Institute continues to receive a great deal of attention from the media. Society President Carl Sagan appeared on the MacNeil-Lehrer NewsHour (PBS) to talk about prospects for future Mars missions with human crews. As in his article in the September issue of *Discover*, Dr. Sagan discussed the human exploration of the solar system as a possible US-Soviet cooperative activity. Clips from "Exploring Other Worlds," the Society's multi-media show, illustrated the segment.

INTERNATIONAL COOPERATION

On September 13, 1984, The Planetary Society's Executive Director Louis Friedman and President Carl Sagan, along with Harold Masursky of the United States Geological Survey and Bernard Burke of the Massachusetts Institute of Technology, testified before the US Senate Foreign Relations Committee about the renewal of the 1977 United States-Soviet Cooperation Agreements. Future Mars exploration was again advocated as a creative and positive program to bring nations together and advance both scientific goals and a benign human future.

The Society's Board of Directors has adopted a policy on international cooperation (see below) and authorized a Planetary Society International Space Cooperation Fund to promote and help develop new international initiatives for major exploration of the solar system. For further information, write the Society at 110 S. Euclid Avenue, Pasadena, CA 91101.

MARS INSTITUTE COURSES

This year our Mars Institute held a wonderfully successful Case for Mars conference and a spirited student contest to design a Mars water recovery system. We also sponsored several college and university classes covering the possibilities and problems of human exploration of Mars. So successful was the Institute that next year we are going to increase the number of courses offered under the auspices of the Mars Institute. Faculty and students interested in initiating courses, projects or seminars at accredited colleges and universities should write us for information.

TELEPHONE INFORMATION LINES

To learn about programs and events related to space science, call Planetary Society information lines: (818) 793-4328 from east of the Mississippi; (818)793-4294 from west of the Mississippi.

MEMBER SURVEY

We have received nearly 5,000 responses to the survey we published in the July/August *Planetary Report*, which makes it one of the largest polls ever taken on space exploration. We are now tabulating the responses and plan to publish the results as soon as possible.

ANOTHER ASTEROID DISCOVERED

The NASA/Planetary Society Asteroid Project, managed by the World Space Foundation, has discovered another Earth-crossing asteroid, 1984QA. The team of Eleanor F. Helin and R. Scott Dunbar of the Jet Propulsion Laboratory, A. Barucci of the European Space Agency, and Steve Swanson of the California Institute of Technology captured the tell-tale streak on a photographic plate taken August 30 with the 0.46 meter Schmidt telescope at Mount Palomar Observatory.

Analysis of 1984QA's orbit indicates that this new object is an Aten asteroid, an object whose orbit has a semi-major axis (the mean distance from the Sun) of less than one Astronomical Unit (the mean distance from Earth to the Sun, 150 million kilometers). With such orbits, the Aten asteroids circle the Sun primarily within Earth's orbit. All four known Atens have been discovered by this asteroid search program.

THE PLANETARY SOCIETY AND INTERNATIONAL COOPERATION

The following is The Planetary Society's position on international cooperation in planetary exploration:

The 1958 National Aeronautics and Space Act, which sets forth the direction of the United States' space program, mandates that "activities in space should be devoted to peaceful purposes for the benefit of all mankind." In particular, cooperation "with other nations and groups of nations, and...in peaceful application of the results thereof" is prescribed.

The Planetary Society promotes and supports cooperation among the various national space agencies in carrying out missions and programs in planetary exploration and the search for extraterrestrial life. It is important that the two major spacefaring nations set an example of international cooperation in the exploration of the solar system. These two leaders in the historic ventures to other worlds over the last few decades have a special responsibility, on behalf of all the nations and peoples of the Earth, to preserve and protect the space environment for the entire human family.

To support that responsibility, and to aid international space cooperation in general, The Planetary Society has been establishing membership liaisons worldwide, and arranging international meetings among space scientists to exchange data and to promote joint projects. Currently, liaisons and membership branches exist in Australia, Canada, China, Japan, Hungary, the Netherlands, and the Soviet Union.

As near-Earth orbit becomes an increasingly familiar locale for practical applications of technology, it becomes progressively more important to develop international support for the peaceful exploration of the solar system. The Planetary Society is committed to developing programs that will help achieve this goal.

VOLCANO—A volcanic eruption can provide conditions similar to those in a thunderstorm: A warm, moist, turbulent cloud containing electrically-charged particles rapidly rises in a convective column, generating lightning discharges. This painting depicts such a situation on Earth, but we are learning that other planets may also have volcanically produced lightning.

Bill Martin is an artist who lives on the northern California coast with his wife Shelley, also an artist. According to Suzanne Foley, curator of the San Francisco Museum of Modern Art, his "...meticulously painted imaginary landscapes exist in a world of expanded reality." Martin's next one-man show will be in April 1985, at the Joseph Chowning Gallery in San Francisco.

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