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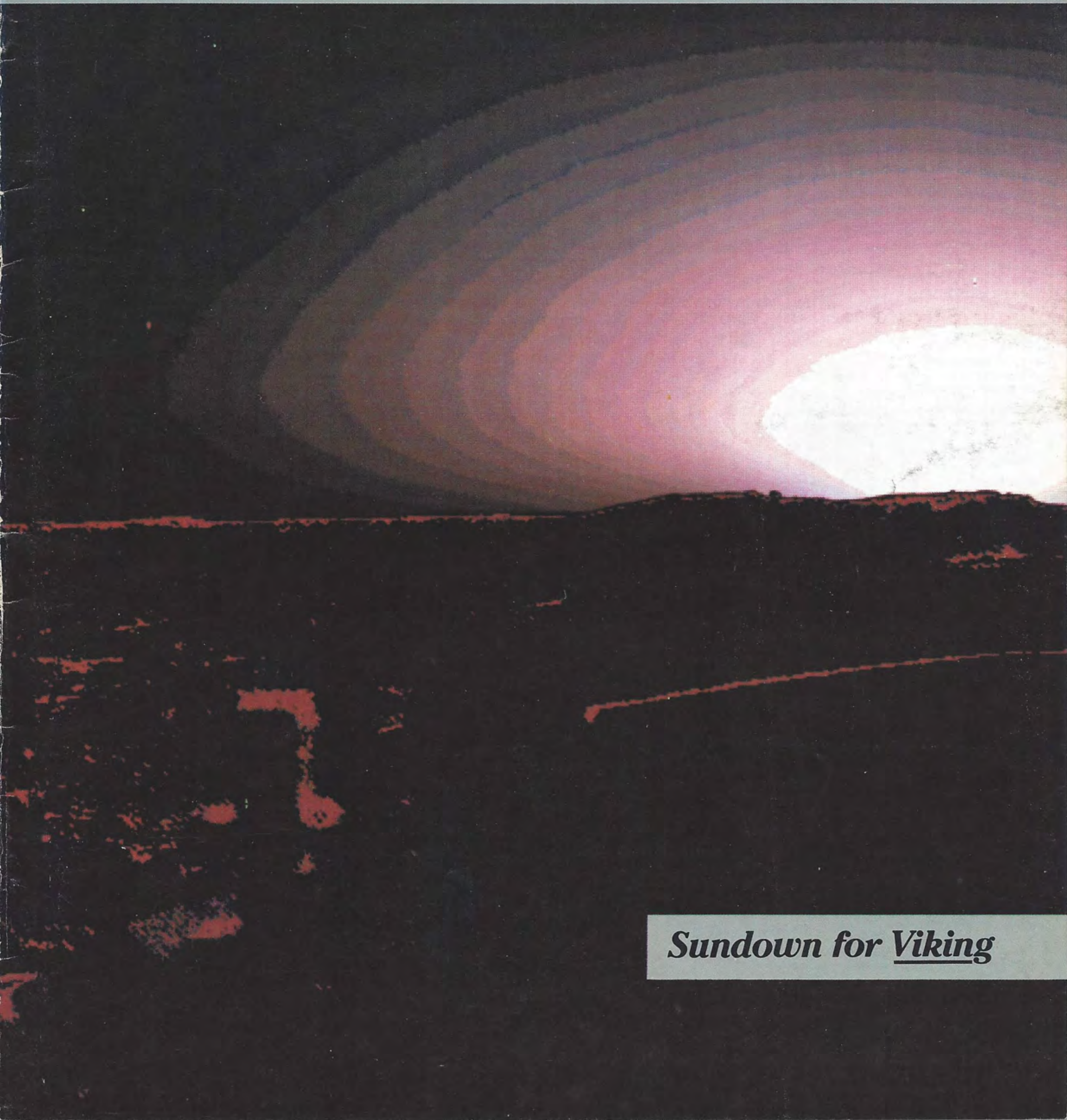

Sundown for *Viking*

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COVER: The Sun has set on Mars, but twilight lingers, casting a reddish glow on the Martian surface (left) and the top of Viking Lander 1 (right). Red dust in the atmosphere scatters the sunlight, producing the color of the sunset. The colored rings in the sky are not real; they are artifacts of severe contrast enhancement produced by computer processing of the camera's transmitted image. *IMAGE: JPL/NASA*

COLUMN REPRINTED FROM THE *PLAYGROUND DAILY NEWS*, FORT WALTON BEACH, FLORIDA:

"Planetary Society is on the right track"
by Del Stone

I recently became a member of an organization which—unlike the more established scientific societies that measure their life spans in musty eons—entered this world a scant two years ago. I'm speaking of The Planetary Society. It is an association of scientists, engineers and lay people dedicated to a common goal: the furtherance of space exploration.

Perhaps what is most refreshing about this organization is the fierce dedication it applies to meeting its objectives. The Society has actually underwritten some of the projects for which it has solicited funding. When the federal government eliminated money for the SETI (Search for Extraterrestrial Intelligence) project, the association stepped in with funding for a new receiver.

These men and women are dreamers, yet their dreams are grounded in the firmament of empiricism. They are engaged in a war—a war to educate their fellow man and muster popular support for space exploration. That presents the Society with a task nearly as formidable as the engineering behind interplanetary projects themselves. The space program has been vilified by a money-conscious Congress. The public has supported space exploration in moments when national prestige seemed at stake, but generally has, for lack of tactile benefits, been lukewarm or occasionally hostile to the question of space program funding.

Backers of the interplanetary exploration effort have watched in frustration as money for their projects has been funneled into the development and procurement of the Space Shuttle delivery system. Retrenchment of the U.S. space exploration effort, especially at a time when other nations are expanding their programs, is risky business. America possesses the resources and technological expertise to lead the planetary exploration field, yet it lags behind while its competitors move ahead. America cannot risk a space exploration monopoly.

The exploitation of space resources—the potential for energy generation, mineral resources, living room, development of technology necessary to utilize those resources and the enrichment of the general field of planetary knowledge—is a plum ripe for the picking. The United States should be aggressively pursuing this opportunity.

Budget cuts and the diversion of funds to the Space Shuttle have sorely hurt interplanetary projects. The Shuttle is a revolutionary delivery system that will make space more accessible to man. Yet it represents only part of the bridge to the stars. Planetary research is laying the groundwork for that bridge, and as anyone can understand, you can't have the one without the other.

The Planetary Society aims to make people aware of the space potential, and the obstacles that are impeding efforts in this direction. □

ANOTHER ASTEROID DISCOVERED

ELEANOR HELIN AND HER TEAM have discovered another asteroid, their fourth this year. Helin describes the new object, 1983 PA, as a "deep Mars-crosser" that does not travel in an orbit that would bring it close to the Earth. 1983PA is a very bright asteroid, suggesting that it may also be very large.

Eleanor Helin's continuing asteroid search is supported by grants from The Planetary Society, administered by the World Space Foundation.

The Last Viking

The first image Viking 1 returned to Earth was of its own footpad. The camera began its scan 25 seconds after touchdown and caught what appears to be falling dust kicked up by the landing spacecraft (the streaks at far left).
IMAGE: JPL/NASA

by Jonathan Eberhart

It's only a machine. Sophisticated, to be sure, packed with advanced electronics, ingenious instruments and keen-eyed cameras, but a machine nonetheless. And yet, after more than six years of receiving its messages from another world and being carefully tended by engineers and scientists, it is difficult to think of the silence that has overtaken it in terms as prosaic as the breakdown of a piece of equipment.

The *Viking* Lander 1 craft sent its first message from the surface of Mars on July 20, 1976; its last on November 13, 1982. During its final year at work it was essentially running on automatic, studying the planet on its own and transmitting its findings to Earth whenever it was asked. It was programmed to do so through 1994—but the requested message of November 19 never came. There was just silence, without a clue as to what might be wrong. The project's engineers could only hypothesize, and they spent the next half-year trying one scheme after another in hopes of triggering a response, but to no avail. The Lander had exceeded its intended 90-day operating lifetime by 25-fold, outlasting its *Viking* 2 twin elsewhere on Mars as well as the two *Viking* Orbiters that still cruise mutely overhead. But its lifetime had now ended.

The concept that ultimately became *Viking* began at the Jet Propulsion Laboratory in the mid-1960s. At that time it was called *Voyager*, a name subsequently passed on to the mission whose spacecraft have now been to Jupiter and Saturn. *Voyager 2* is still on its way to encounters with Uranus in 1986 and Neptune in 1989. The original Mars-bound *Voyager* was to have been launched in 1973, two years after the *Mariner 9* orbiter that discovered such Martian spectaculars as Olympus Mons and Valles Marineris. But budget cutbacks in the late 1960s brought the Martian *Voyager* to a halt.

The reduced-scale *Viking* mission, managed by NASA's Langley Research Center, would require two launches, each carrying a JPL-built, *Mariner*-based orbiter and a biologically-sterilized landing craft to be built by the Martin-Marietta Corporation. Even with its diminished scope, *Viking* would be an audacious undertaking—four spacecraft to be controlled on a day-to-day basis by a vast flight team of nearly 800 people. And its primary goal—a landing on Mars—would be an attempt to reverse an unbroken record of failures. The United States had not even tried such a feat (and only four of the seven *Surveyors* had worked on the Moon). But the Soviet Union had tried—at least four times by the first *Viking* launch. Those four attempts, called *Mars 2, 3, 6* and *7,* resulted in one complete miss, one (and possibly a second) crash, and a post-landing transmission lasting perhaps 20 seconds, long enough to include only a narrow slice of a single, featureless television frame.

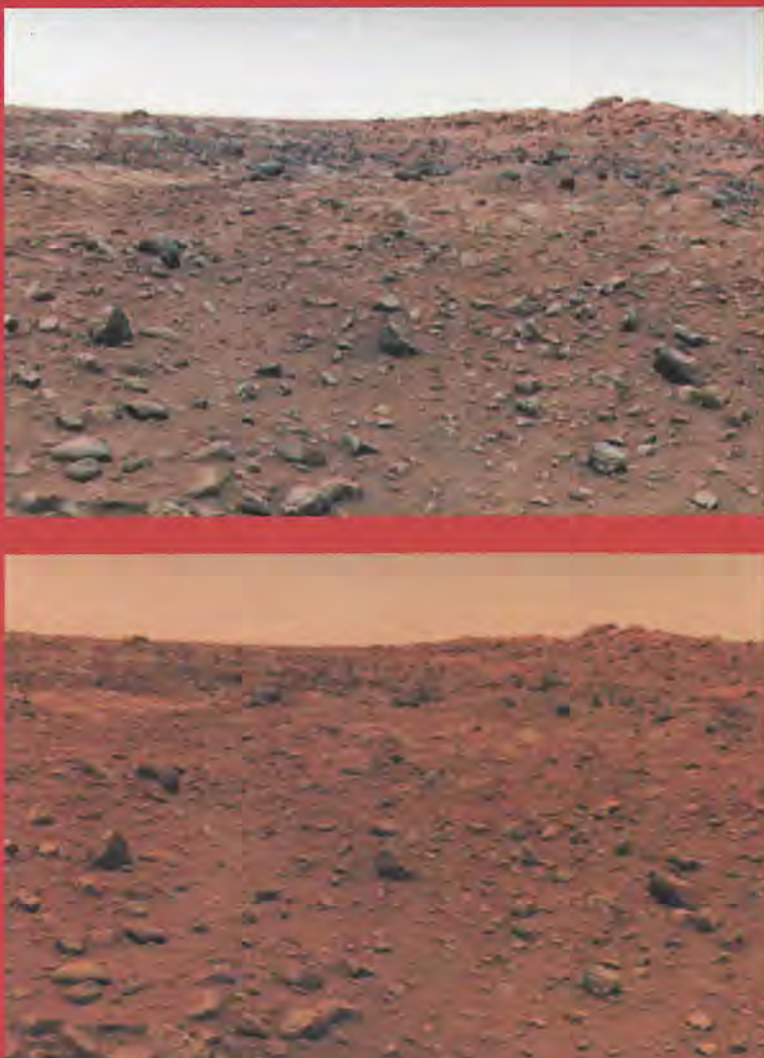
Launch Drama

Few if any spacecraft have had completely trouble-free launches and, seen against the history of past Mars-landing attempts, the launch of *Viking 1* (the combined Lander and Orbiter) continued the drama. On August 11, 1975, with liftoff only three hours away, engineers discovered a minor technical problem which they expected would take about a day to fix. With that work underway, however, other problems surfaced, leading to the decision to swap the original craft with what had been *Viking 2,* and repair the faulty machine in time for the second "launch window."

The new *Viking 1* took off on August 20, nine days late, aimed to take up orbit around Mars the following June 19. The Orbiter's primary purpose was to provide high-resolution pictures of the proposed landing sites, largely selected from *Mariner 9* imagery, to confirm their safety. The Lander was to be detached from the Orbiter for its momentous touchdown on the 4th of July in the United States' bicentennial year.

The new *Viking 2* was launched 20 days after its predecessor, on September 9 (following an eight-day delay of its own due to an antenna problem). It would reach Mars orbit the next August 7, with its Lander scheduled for a descent on September 4.

Finding safe landing sites was a painstaking process. *Viking 1* returned pictures clearer than any that had come before, but these only added to the site-searchers' tension,



A clear blue sky seemed to hang over Viking Lander 1 in the first panorama of the Martian horizon (top). But this illusion of an Earth-like firmament did not last long. Once images of the color charts affixed to the Lander had been returned to Earth, Viking scientists, prodded by James Pollack of NASA's Ames Research Center, were able to properly balance the color—and reveal the red Martian sky (bottom). How could they have mistaken a red sky for a blue one, especially since the atmospheric pressure was known to be too little to produce a blue sky by Rayleigh scattering as on Earth? Former Project Scientist Conway Snyder explains: "We didn't have enough experience with this thing. People assumed the sky was blue and that's the way it came out. It's like adjusting the color balance on a TV set; you twist the knob until the girl in the picture looks natural. If it turns out that the girl is really green, you're going to get it all wrong."
IMAGE: JPL/NASA

revealing pits, knobs and rough spots—each one further reminding the scientists of hazards that might lie below the camera's limit of resolution. So the search was expanded from the primary region in Chryse Planitia to areas as distant as Tritonis Lacus, 7,000 kilometers away from the planet. As the quest continued, the planned July 4 landing was scrapped. Finally, a site was chosen back in another part of Chryse.

And then, with only days to go, yet another concern arose. Radar measurements from the Arecibo radio telescope in Puerto Rico indicated that the laboriously chosen spot, although good in the Orbiter TV images, had a "mean slope" (an indication, from *Viking*'s standpoint, of its roughness) about twice the Martian average. One more slight shift was made, to a spot on the western slope of Chryse basin, only about 740 kilometers from the original landing site. The landing was set for July 20.

Touchdown!

"Touchdown! We have touchdown!" The voice of Richard A. Bender, head of the Lander Performance Analysis Group, rang clearly over the control center communications system at JPL. Veteran project manager James Martin had tears in his eyes. A decade of effort, $1 billion, the combined labors of some 10,000 people...and the first thing the *Viking 1* Lander did was to examine its own foot.

In the razor-sharp image could be seen details as tiny as pea-sized rivets on the Lander's footpad (one of three), and even smaller grains of surface material both tossed into the footpad and lying about the rock-strewn terrain. Minutes later, a tiltable mirror rose to reveal the surroundings all the way out to the horizon. Within an hour, a compact package of meteorology sensors reported on the atmospheric temperature and pressure, wind speed and direction—the first weather report from another world.

There were problems. The sensors in the craft's seismometer refused to come "uncaged" from the safety-locked position in which they had made the trip from Earth. For two days running, the Lander transmitter inexplicably turned itself on with only 1 watt of power instead of 30. Then, equally mysteriously, it fixed itself. The primary receiver developed a 90 percent reduction in sensitivity, but a backup unit was there to take its place. VL-1 was on the job.

Its first color image produced little surprise when it showed a blue Martian sky, but careful color balancing revealed the true color to be more of a light salmon pink —a washed-out version of the surface color, caused by dust suspended in the thin Martian CO_2 atmosphere. A few days later, the Lander's soil-sampling arm was gingerly sent out to retrieve the first surface samples of Mars. It delivered the material to a gas chromatograph/mass spectrometer (seeking organic molecules), an x-ray fluorescence spectrometer (to determine the element-by-element chemistry) and a $50 million, three-experiment package designed to conduct the first *in situ* search for signs of extraterrestrial life. The very first "biology" results galvanized the entire *Viking* team—and millions of *Viking*-inspired Mars-watchers around the world—when they showed a soaring release of oxygen from the sample in one instrument. As a sign of possible Martians, however, the message was—and remains—inconclusive. It now appears that the oxygen release is a peculiar property of Martian soil; presumably, solar ultraviolet light penetrates the thin Martian atmosphere and generates oxidizing chemical compounds in the soil. Orbiter 1, meanwhile, circled overhead, adding to its spectacular picture gallery and reporting on the temperature and water content of the atmosphere.

A Second Arrival

Viking 2 arrived in Mars orbit on August 7, and its Lander's descent was set for September 3. The second time, even for such a complex task as guiding a robot spacecraft down to the surface of another planet, ought to be at least a bit more relaxed than the first. But it was not to be. Lander 2's descent to Mars was a knuckle-whitening three hours of tension, beginning just seconds after its separation from its orbiting carrier when, with no warning, the power supply to one of the Orbiter's three main stabilizing gyroscopes simply shut itself off. Seconds later, another one followed suit, leaving the Orbiter to turn aimlessly until its high-gain antenna—a key element in relaying the Lander's radio signals—was no longer pointed at Earth. Although the Lander was flying on instructions already stored in its computer memory, the disappearance of the Orbiter's relay link meant that the whole *Viking* team, for all its advanced technology, was abruptly thrown into darkness.

The Orbiter's computer soon activated its wider-reaching low-gain antenna, but the weak signal was able to indicate only that the Lander was alive and sending. All else was a mystery, heightened by the Lander's reaching the surface 32 seconds later than expected. The cheer that greeted its touchdown was louder than the one that had met Lander 1, when there was nothing to worry about but an untried spacecraft, an unsampled atmosphere and a planet that had apparently killed off every previous vehicle to make the attempt.

As hoped, the four *Viking* spacecraft have provided more information about the red planet than all the previous centuries of Mars-watching. They would have done so even if the Orbiters had merely fulfilled their primary purpose, lasting long enough to get the Landers down, and if the Landers had merely made it through their designed 90-day lifetimes. But the *Vikings* were tenacious beyond their mentors' wildest expectations.

The first to expire was Orbiter 2, which succumbed to a series of steering-gas leaks on July 25, 1978—after 718 days around Mars. Its Lander survived nearly twice that long—1,316 days—before its last message came on April 11, 1980. Apparently its batteries would no longer hold their charge. Orbiter 1, the first *Viking* to go on duty, lasted longer still—1,509 days—getting every last gasp out of its declining fuel supply. Engineers finally silenced its transmitter while they could still be sure of getting the message through. Together, the two Orbiters took 51,539 pictures of Mars, mapping 97 percent of its surface with a resolution of 300 meters or better, including a fourth of the planet with 25-meter resolution. Lander 2, besides providing panoramic images of its own, transmitted more than 1 million meteorological measurements from its miniature weather station.

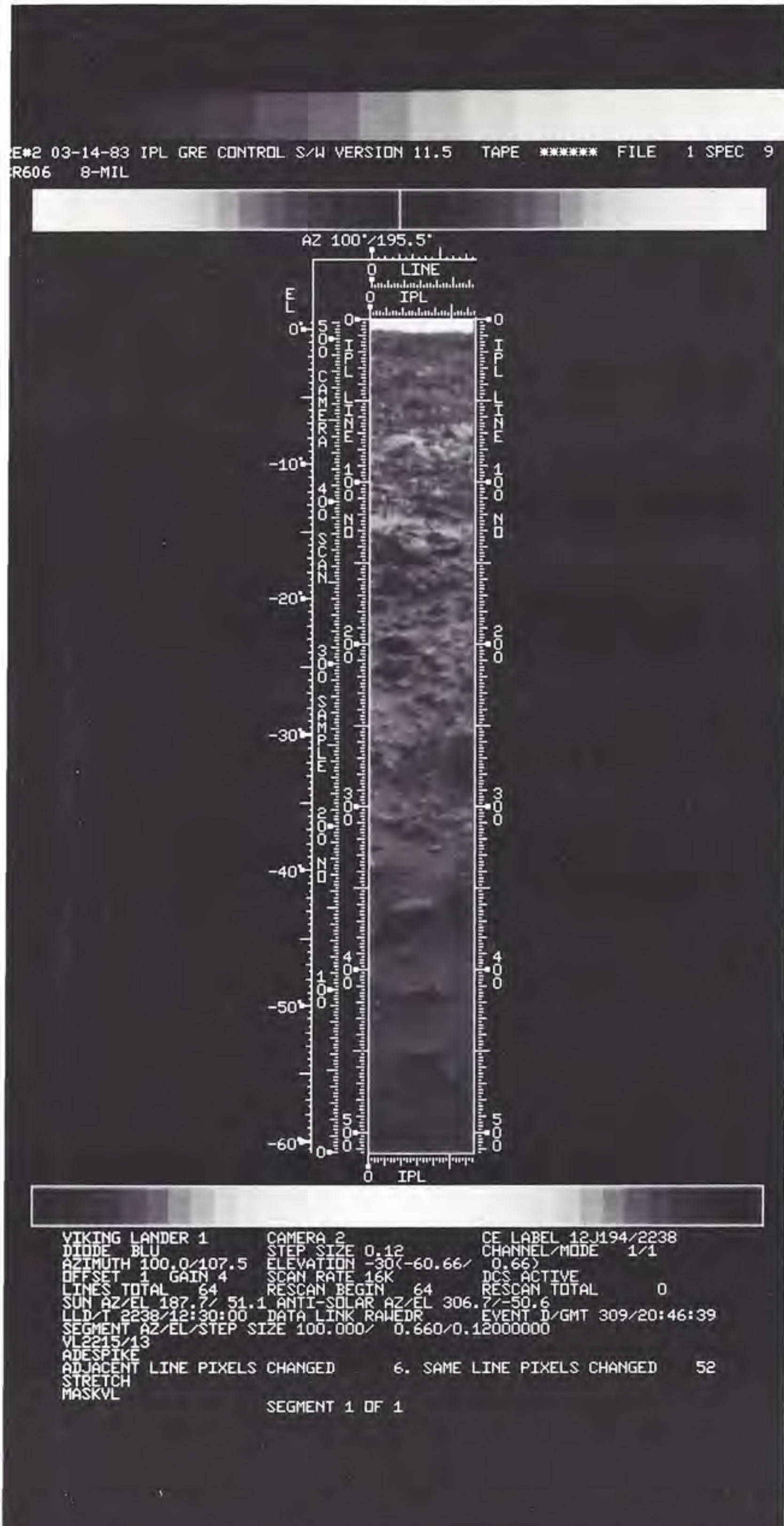
An "Eternal" Mission

But Lander 1 seemed inclined to stay on duty forever. By late 1980, the *Viking* flight team, once 800 strong, had dwindled to a handful, but the Lander's nuclear power supplies were perfectly healthy. Before it had ever landed on Mars, the Lander's computer had been programmed to conduct the whole primary mission (those first 90 days) on its own, in case some malfunction had prevented updates from Earth. It was now programmed in a similar fashion for its "eternal" mission. It would go on taking a picture every seven Martian days (24 hours and 36

(continued on next page)

***ABOVE:* On January 7, 1981, *Viking* Lander 1 was officially designated the Thomas A. Mutch Memorial Station. "Tim" Mutch was the much-admired leader of the *Viking* Imaging Team; he supervised the construction and operation of the cameras that made the Martian surface familiar to people on Earth, and later became NASA Associate Administrator for Space Sciences. An experienced mountaineer, he fell to his death in October, 1981 while climbing in the Himalayas. A plaque honoring Tim Mutch will be placed on the Lander by the first humans to visit this remote outpost on Mars. In this painting, artist Don Davis portrays the Thomas A. Mutch Memorial Station early in the next century.**

***BELOW:* A large boulder, nicknamed "Big Joe," is *Viking* Lander 1's companion on the Martian plain. Lying only 9 meters from the Lander, this 2-meter-wide rock was frequently observed by the spacecraft. In images of this boulder, project scientists discovered one of the few small-scale geomorphological changes seen on another planet: a small amount of soil "slumped" at the lower right end of the boulder. Scientists speculate that the slumping may have been caused by the Martian wind.** IMAGE: JPL/NASA



The last image from Viking Lander 1 was taken on November 5, 1983—2,238 Martian days (6 Earth years, 108 Earth days) after touchdown. It was part of a series designed to survey areas of Chryse Planitia under identical lighting conditions to look for changes in the atmosphere and surface. The ground appears dark and the shadows diffuse, suggesting that a dust storm, detected a few weeks earlier, was still blowing. The calibration lines, gray bars and data on the imaging system are used by scientists to analyze the picture.

IMAGE: JPL/NASA

minutes each) and monitoring the wind, sending back the results every time earthlings requested them. On January 7, 1981, the craft even got a new name: the Thomas A. Mutch Memorial Station, assigned in honor of the former chief of the *Viking* Lander Imaging Team who had died the previous October in a mountain-climbing accident.

Based on projections of the life remaining in the nuclear power supplies, the "eternal mission" (called the Monitor Mission in official NASA parlance) was programmed to last through December, 1994. A typical Monitor Mission message was the one received at JPL last November 13, when the Lander had been at work some 2,299 Earth-days (6 years, 108 days), or 2,238 days on Mars. Its typically sharp picture was taken as part of a series designed to monitor the scene over time, under identical lighting conditions, to seek changes on the surface and in the atmosphere. The dark-looking ground and diffuse-edged shadows in the image suggested that a Martian dust storm, first spotted weeks earlier, was still underway. How long would the storm continue? Another message was requested on November 19.

It didn't come.

Silence

Nothing else has ever been heard from the Mutch Memorial Station. One proposed explanation, says JPL's George Gianopulos, then head of the tiny *Viking* team, was that erroneous commands had destroyed the Lander's knowledge of the Earth's position in the sky, by which the Lander was able to aim its antenna toward home. After careful analysis, the team felt that they understood the antenna's presumed new motion and tried sending messages at revised times, but without success. Another possibility considered was that the batteries might have gotten weak enough to trip a built-in switch designed to save power by shutting off everything but the radio receiver; everything —including the antenna-pointing motor and the all-controlling computer, which in turn was necessary to recharge the batteries. An elaborate set of instructions was devised, requiring three separate messages from Earth, spread over a 10-day period. Still nothing. By now, the JPL group was receiving aid from colleagues at Martin Marietta Corp., the Lander's builder, but to no avail. The craft was variously commanded to switch to its backup transmitter, to reconfigure individual components and to try other approaches. The engineers even tried simply letting it alone for nine weeks, in hopes of activating a built-in program that was supposed to make the Lander send a message if it had not heard from Earth in that time. But silence reigned.

The final attempt came more than six months after the November 19 message had failed to arrive. On May 21 of this year, after some commands to reconfigure the Lander's transmitter had fared no better than the rest, Gianopulos drafted a report for officials at NASA headquarters in Washington. "It will be my recommendation," he said that day, "that further attempts be terminated, and that the *Viking* Lander Monitor Mission be declared ended."

That night, a group of *Viking* colleagues and their friends got together and drank a toast to Lander 1. Although the outcome of their efforts to restore it had been expected for some time, it was difficult to abandon such a long association.

But then, it *was* only a machine.

Jonathan Eberhart is the Space Sciences Editor of Science News. *He won the American Association for the Advancement of Science Writing Award for his coverage of the* Viking *mission.*

SEEING THROUGH SAND

by Charles Elachi and Ronald Blom

Over the last two decades, spaceborne imaging sensors have made familiar the faces of the planets from Mercury to Saturn. Cameras on the *Gemini* and *Apollo* spacecraft photographed the Earth from a new perspective. Multispectral scanners on the Landsats revealed intricate patterns of topography, vegetation and human activities. *Mariners, Pioneers, Vikings* and *Voyagers* used complex television systems to transmit electronic representations of our neighboring planets back to the Earth.

Most of these sensors use visible light and near-infrared radiation. In this narrow region of the electromagnetic spectrum, the image represents radiation reflected off only the top few microns (a micron is a ten-thousandth of a centimeter) of a planet's surface. Thus, these instruments "see" only surface features. A few spaceborne sensors operate in the thermal infrared and microwave regions of the spectrum (with wavelengths much longer than visible light), receiving the natural thermal radiation emitted from regions within some tens of centimeters of the surface. Such sensors, however, have a relatively poor ability to resolve fine detail.

In the last five years, two high-resolution civilian imaging radar systems have orbited the Earth: the *Seasat* SAR (synthetic aperture radar) in 1978, and the Space Shuttle Imaging Radar-A (SIR-A) in 1981. Imaging radars are active sensors; that is, they provide their own illumination. These sensors operated at a wavelength of 23.5 centimeters (cm) which, for certain terrestrial materials such as very dry sand, can penetrate through a layer a few meters thick.

Since the late 1960s, spacecraft designers have been studying imaging radars to map the surface of Venus. These systems could penetrate the persistent cloud cover that has hidden Venus' surface from other orbiting imaging sensors. The Venus Radar Mapper (VRM), planned for launch in 1988, will use radar to image the planet's surface with high resolution. Lessons learned from both *Seasat* and Shuttle radars will help engineers to develop the instrument for VRM.

SIR-A flew on the second Shuttle flight and returned radar images of many parts of the world, including the northeastern part of Africa, covering parts of Egypt, Sudan, Libya and Chad. This area forms the core of the vast Sahara desert and is one of the driest places on the surface of the Earth. Rain falls at any one place only once every 40 to 50 years. The Saharan sun can evaporate surface moisture 200 times faster than any moisture can form. In such a hyperarid climate, a radar wave with a wavelength of 25 cm (half a million times longer than visible light) can penetrate a few meters deep, reflect off subsurface features, and return to the imaging system. Radar images can show subsurface features invisible to the human eye or to other imaging systems operating in visible or infrared light.

A large portion of the Sahara seen by SIR-A is covered with a windblown sand sheet, up to a few meters thick. This blankets most near-surface features in this extraordinarily flat terrain. *Landsat* images of the area show a barren, windswept, sand-covered desert. Few details in these images indicate that the Sahara was ever anything but a desert. In vivid contrast, the radar images reveal a now-buried landscape sculpted by running water. These newly revealed stream beds give us new insight into the history of this inhospitable region.

To verify that the Shuttle radar actually mapped sand-covered geologic features, scientists from the United States Geological Survey (J. McCauley, C. Breed, G. Schaber and M. Grolier), the Egyptian Geologic Survey (B. Issawi and colleagues), and the Jet Propulsion Laboratory (the authors) traveled to the Sahara. We made surface observations, dug pits to determine sand sheet thickness, and collected samples for laboratory measurement of moisture content and electromagnetic transmission. This field work, the laboratory measurements, and theoretical model analysis have led us to conclude unambiguously that the radar images portray a surface completely covered with a sand sheet up to 2 or more meters thick.

In the field, we determined that this sand sheet gives little or no surface indication of the fluvial features cut by rivers, seen on the radar images. Diggings in several sites showed that the sand is wind-blown and ranges from 0.8 to 2.2 meters thick. Subsequent measurements on samples of this sand showed that the radar waves could penetrate to depths of 1.6 to 6 meters, a distance called the "skin depth." Theoretical modeling showed that the covering sand layer actually enhances the radar return from the subsurface interface as long as the sand layer is thinner than the skin depth. This is because at the top of the sand layer, the waves are refracted, or bent, leading to a steeper incidence angle on the old subsurface, thus increasing the net reflection of the radar waves.

These radar images give clear and direct evidence that, during some periods in the past, this now extremely dry region of Africa was not so forbidding. The images clearly show channels with river valleys wider than the present Nile Valley and drainage networks extending for hundreds of kilometers. In the last two decades, field researchers (including those on our expedition) digging down to the base of the sand layer have found numerous human artifacts from the Acheulean period (40,000 to 100,000 years ago) and broken ostrich egg shells. These indicate that the area was inhabited before it evolved into its present hyperarid condition. Radiocarbon dating of the egg shells gives 3 distinct age groups, between 5000 and 6000 years ago. The latest period is as recent as the early Egyptian pyramids. We believe that the climate of this region of northeastern Africa has changed back and forth between the present hyperaridity and a wet savannah environment, allowing the region to be inhabited at different periods over the last 100,000 years.

This radar's capability to penetrate surface cover and portray hidden terrains in arid environments has implications for both Earth and planetary exploration. On the 17th flight of the Shuttle, now scheduled for August, 1984, a much more complex imaging radar (SIR-B), with an imaging resolution of 20 meters, will be flown. During that mission, the radar will image one-third to one-half of northeastern Africa, providing us with a large-scale picture of the geologic features now covered by the sand sheet.

The surface of Venus has finally been revealed through the *Pioneer* Venus radar altimeter, which has been orbiting that planet since late 1978. This spacecraft has provided a reasonably detailed map of Venus' surface, despite its relatively coarse 25-kilometer resolution capability. In 1988, the Venus Radar Mapper (VRM) will map most of the surface with a resolution better than 500 meters. Because of the penetration features of the radar, we expect to learn much about that planet's surface morphology, extending the pioneering radar results of the Arecibo Observatory on Earth, and the *Pioneer* Venus radar system.

Our ability to see through thin surface coverings could also help us to understand the erosional processes on Mars. "Stripping" the top few meters of dust off the surface might provide new insight into the extent of both fluvial and aeolian (wind-blown) processes there. Also, solidly frozen water and dry ice (frozen carbon dioxide) are also rather transparent to radio waves. We may be able to acquire images of polar areas permanently covered by ice sheets. And imagine what we might see with radar on Saturn's moon Titan or the icy satellites of Jupiter!

Charles Elachi is a Senior Research Scientist at the Jet Propulsion Laboratory of the California Institute of Technology. He is the Principal Investigator on SIR-A and SIR-B. Ronald Blom is a Senior Scientist in the Imaging Radar Geology Group at JPL. He has studied the geologic applications of imaging radars for both terrestrial and planetary research.

TOP: Smooth fragments of ostrich egg shells lie scattered in the sand, evidence of a far more clement climate in the past. Such clusters of egg shells are often found in association with stone tools. The measuring stick in the background is two meters long. PHOTO: JPL/NASA AND U.S. GEOLOGICAL SURVEY

ABOVE: Stone tools such as this small hand ax are common near the courses of prehistoric rivers seen on the SIR-A radar images. Each division on the measuring stick is one centimeter. PHOTO: JPL/NASA AND USGS

RIGHT: This figure illustrates the difference between the present barren sandy desert surface seen in the Landsat images (yellows and oranges) and the surface carved by fluvial processes, lying just beneath, revealed in the cross-cutting SIR-A radar image. The SIR-A image covers an area 50 kilometers wide by 300 kilometers long. The largest river valleys seen here are as wide as the present Nile Valley and represent millions of years of erosion in a much wetter climate. IMAGE: JPL/NASA AND USGS

LEFT, TOP: Two major Tertiary Period riverbeds run together in this SIR-A image of northwestern Sudan. An ancient flood plain, about as wide as the present Nile flood plain, appears as a dark area running from the top to the bottom of this image. At the right center, another major river joins it. Small Quaternary Period channels can also be seen. IMAGE: JPL/ NASA AND USGS

LEFT, BOTTOM: This Landsat image shows the same area of the Sudan. Two meters of wind-blown sand almost completely cover the present landscape. Note the sand dunes (bright streaks) near the confluence of the two rivers. These dunes are completely invisible in the SIR-A image because microwaves pass through them. IMAGE: JPL/ NASA AND USGS

VENUS REVEALED

by James B. Garvin, Maria T. Zuber and Paul Helfenstein

Soviet Venera spacecraft landed on the hostile surface of Venus in 1975 (Venera 9 and 10) and again in 1982 (Venera 13 and 14). Their cameras obtained the first panoramas of the planet's surface. To function long enough to transmit complete pictures to Earth from Venus, where the temperature reaches 450 degrees Centigrade and the pressure 90 atmospheres, the Venera cameras were designed with few moving parts. They were installed at a height of 90 centimeters (cm) and inclined 50 degrees from the surface. From this single position, they could see from the base of the spacecraft to the distant horizon.

This introduced distortion that made it hard to analyze some features in the Venera pictures. Just as a wide scene must be photographed by different lenses to reproduce what the eye would see, Venus' surface must be observed from various perspectives to minimize distortion. Therefore we have transformed the pictures into two different perspectives. One view best represents what the eye would see looking toward the horizon, while the other shows what would be seen looking down at one's feet. We produced the new images using a computer algorithm that mathematically remaps picture elements (pixels) from the original Venera pictures into their correct transformed positions.

From these transformed images we have analyzed the physical characteristics of the four landing sites on Venus. Two possible origins are most consistent with our present observations of the planet's surface: (1) thin lava flows in various stages of erosion, or (2) thin sedimentary layers produced by as-yet-unknown processes, such as wind or chemical weathering.

In comparing the pictures from Venera 9 and 10 with those from Venera 13 and 14, we see a noticeable resolution difference. The Venera 9 and 10 pictures show pebbles as small as 1 cm, while those from Venera 13 and 14 show objects 0.4 cm in length. For comparison, the Viking Lander pictures of Mars (in the high-resolution mode) had 0.15 cm resolution. Because of its thick cloud layers, Venus is continuously overcast, with no direct sunlight. Shadows are diffuse and occur in all directions.

The images presented here have been prepared with the photographic assistance of Sam Merrell, and through cooperation with Soviet scientists at the Vernadsky Institute in Moscow. Additional details can be found in our upcoming article in the Journal of Geophysical Research.

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FIGURE 1: ***Views of Venus from Venera 9 (top) and Venera 10 (bottom). These automated probes landed approximately 2000 kilometers (km) apart in the foothills of Beta Regio, a mountainous region possibly volcanic in origin. The distance to the horizon, seen at the extreme right and left, is probably about 100 meters, and even less in the leftmost part of the Venera 9 picture where a double horizon is faintly visible. The rock fragments strewn about Venera 9 could be the result of a rockslide down a small hill. The bedrock plates near Venera 10 could represent either eroded lava flows or sedimentary terrain. The rake-like device in the middle right of each picture is 40 cm long and was designed to measure the density and composition of the surface.***

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FIGURE 2: (See previous page) Transformed version of the Venera 9 picture. The geometry in this panorama is equivalent to that used by the Viking Landers on Mars. Objects near the horizon appear relatively undistorted when compared to the same objects in Figure 1.

FIGURE 3: Transformed version of the Venera 10 picture, with the same characteristics as Figure 2. The bright, segmented object in the middle nearfield is the camera lens cap and is 40 cm long. Venera 10 landed on rolling plains, which cover over 60 percent of Venus' surface.

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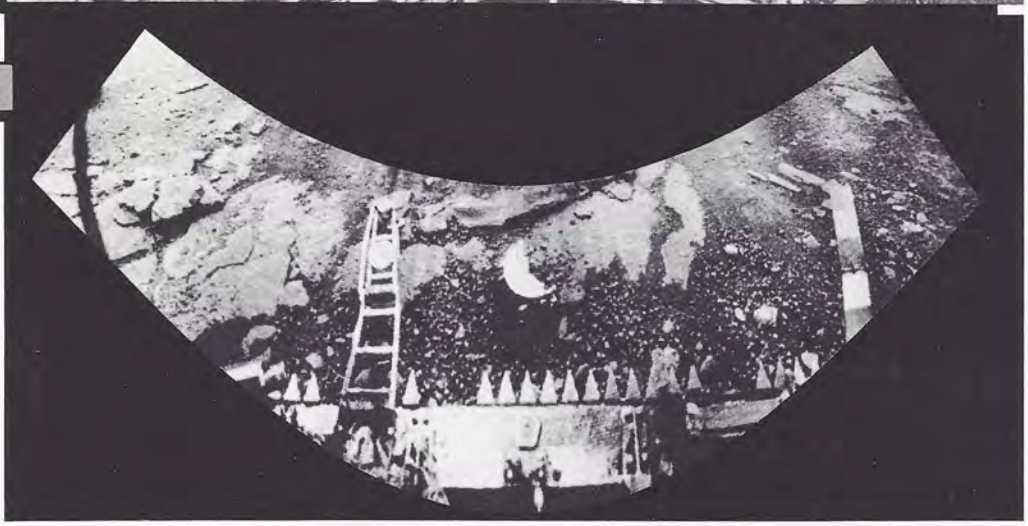

FIGURE 4: First view of the surface of Venus taken by the Venera 13 lander. The arm-like device at middle left is 60 cm long and was designed to measure the mechanical strength of rocks and soils. The semicircular device in the middle of the picture is the camera lens cap. The shaded chart at the middle right is a color reference chart. The teeth on the lander ring were used to stabilize the spacecraft during its free-fall descent through the dense atmosphere. Turbulence during descent to the surface may have blown away a fine layer of soil previously covering the pebbles that are common about the spacecraft base.

FIGURE 5: Transformed version of the Venera 13 picture shown in Figure 4.

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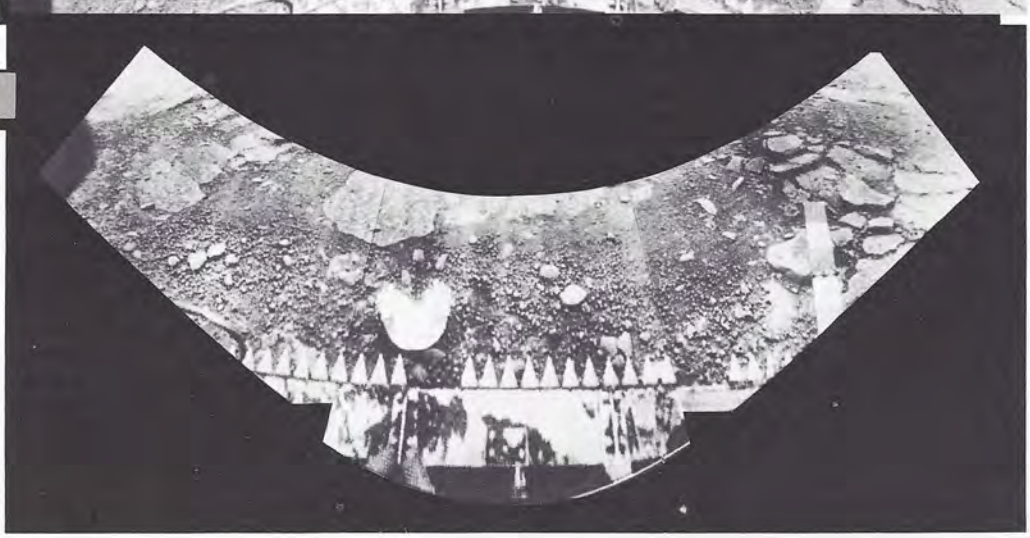

FIGURE 6: View of the back side of the Venera 13 landing area in the original perspective. Notice the dust on the lander base and the "rock pile" at the extreme right.

FIGURE 7: Transformed version of the Venera 13 back side picture. The spacecraft landed with a tilt of approximately 8 degrees.

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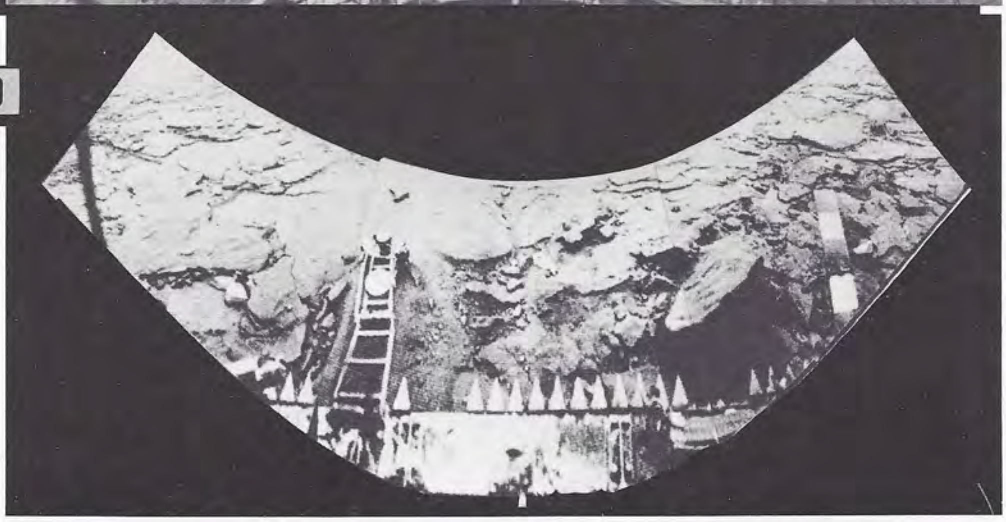

FIGURE 8: First view of the surface from the Venera 14 lander. Notice the almost complete absence of dust or soil in the picture. As many as 5 layers of rock have been recognized in this scene. The large (60 cm-long) fragment in the middle right appears to have broken from one of the bed-rock layers. The surface resembles certain terrestrial lava flows, as well as continuous outcrops of slate. Geochemical measurements suggest that the rocks at this locality are like the lava flows that cover the Earth's ocean floor in many places. This contrasts with the composition of the Venera 13 site, where the rocks are like some uncommon terrestrial lavas having a high potassium content.

FIGURE 9: Transformed version of the Venera 14 picture shown in Figure 8.

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FIGURE 10: Picture from the back side of Venera 14 displaying an almost continuous bedrock surface. Note the absence of dust on the lander base. Directly above the camera lens cap in the middle of the picture is an eroded layer with a "window" in it revealing an underlying layer.

FIGURE 11: Transformed version of Figure 10.

12

FIGURE 12: Plan view transformation of the front side of Venera 13. Rock shapes near the lander are almost completely undistorted in this perspective.

James Garvin, Maria Zuber and Paul Helfenstein are graduate students in planetary geophysics at Brown University.

The Hungarian Connection
by Tamás I. Gombosi

We recently announced that we have established an official liaison with the Hungarian Astronautical Society to expand the popularization of space exploration. Because this is the first such official connection on the popular level, we believe it is very significant and hope that it will be the first of many cooperative efforts to build global interest in exploring the solar system. This report is filed by our colleague, Dr. Tamás Gombosi.

When Americans are asked about United States-Hungarian scientific connections, they might mention the names of von Neumann, Szilárd, or Teller as individuals who significantly influenced the development of science in the United States. They were, however, only the most visible Hungarians in postwar U.S. science; a number of others also played important roles. There is even an anecdote—told mainly by Hungarian-Americans—about a U.S. science board which in the late 1940s discussed some questions concerning nuclear physics. As was more or less typical at that time, the participants had problems communicating in English. After some confusion, one of them came up with the solution: "But gentlemen, why do not we all speak Hungarian?"

American space enthusiasts know other Hungarian connections as well. Some of them have probably heard about Zoltán Bay who, in 1946, was the first to register radar signals scattered back from another celestial body, the Moon, and most of them know the name of Tódor (Theodor) von Kármán, a pioneer in fluid dynamics and founder of the Jet Propulsion Laboratory.

Now there is a new type of Hungarian connection for the 100,000 plus members of The Planetary Society. In order to popularize and promote interest in international programs to explore the solar system, the Hungarian Astronautical Society (HAS) recently became affiliated with The Planetary Society. This connection emerged from the events commemorating the 20th anniversary of the *Mariner 2* encounter with Venus, where I had the honor of presenting a paper about Venus exploration and the international VEGA program to fly by Venus and intercept Halley's Comet. During the celebrations I talked with some of the Society's Directors about the goals and plans of both the Planetary and Astronautical Societies. We concluded that there were a number of common goals and interests, and agreed to initiate contact between the two Societies. Planetary Society Executive Director Louis Friedman and Astronautical Society President Iván Almár exchanged letters of agreement about affiliating HAS with The Planetary Society.

I would like to introduce the new Hungarian connection to the readers of *The Planetary Report*. In our country there are several non-governmental bodies dealing with space activities: the Association for Popularization of Science, and several member organizations of the Federation of Technical and Scientific Societies, especially the Hungarian Astronautical Society. This latter group has three fundamental goals: to organize amateurs and space enthusiasts, to promote a scientific forum for the few hundred Hungarian space professionals, and to serve as a special interest group for the Hungarian space community. The Society regularly organizes widely-attended open lectures on "hot" topics, such as the search for extraterrestrial intelligence and space weapons. We also have regular access to the news media, where we inform the general public about the newest developments in space activities.

In our country space science is organized by the Hungarian Intercosmos Council operating under the guidance of the Hungarian Academy of Sciences, while space applications are partly supervised by other governmental bodies. The Intercosmos Council has five permanent working groups; they coordinate activities on space physics, space communications, space medicine and biology, remote sensing, and space meteorology. As a result of the very limited financial resources available in a small country (Hungary has a population of only 10.5 million), the research strategy has to be highly selective. It is impossible to concentrate on every interesting aspect of space science; instead our scientists try to select those questions where they can contribute the most to international projects. This strategy has the advantage of providing a major role in some highly visible projects (for instance Hungary's share in the Venus-Halley's Comet program is second only to the Soviet Union's). At the same time, this has a much higher than average risk.

A natural consequence of this research strategy is vital dependence on international cooperation. The Intercosmos program provides a solid basis for Hungarian space research. In the frame of this cooperation we have had opportunities to participate in the study of the ionosphere, magnetosphere, the interplanetary medium, the Moon, Mars, Venus, and even minor bodies of the solar system. The flight of Lt. Colonel Bertalan Farkas, the first Hungarian cosmonaut (who, according to female sources at NASA Headquarters, is considered the most handsome of all astronauts) was also made possible by the Intercosmos cooperation. Hungarian research centers also cooperate with other countries and organizations to mutual advantage. They have an agreement with NASA, and are discussing additional cooperation with NASA, ESA (the European Space Agency) and several western European countries. Hungary is also involved in the interagency activities of ESA, Intercosmos, ISAS (Japan) and NASA to optimize the science return from ground-based and *in situ* observations of Halley's Comet.

We, at the Hungarian Astronautical Society, are looking forward to our American connection and wish further success to The Planetary Society.

Dr. Tamás Gombosi, a space physicist, is the Secretary of the Hungarian Astronautical Society and also of the Space Physics Working Group of the Hungarian Intercosmos Council. He is the only scientist to have participated in both the United States and the Soviet Venus exploration programs, and is now the Hungarian science coordinator for the VEGA (Venus-Halley) mission.

Society to Fly on Shuttle

The Planetary Society will fly on the Space Shuttle in 1985. A group of students at the California Institute of Technology, known as the "Student Space Organization," has come up with an innovative idea for simulating and studying Saturn's rings using a Getaway Special on the Shuttle. The flight is scheduled for March, 1985, and, as part of our commitment both to educational projects and to the use of the Shuttle for science, The Planetary Society is paying for the experiment. We hope this work will seed further exploration and studies about Saturn's rings. The rings are a repository of information about the evolution of planetary systems, and their dynamics are only very cursorily understood.

News & Reviews

by Clark R. Chapman

Consider the dramatic scenario of an asteroid crashing to Earth 65 million years ago, eradicating the fabled dinosaurs and opening up the ecological niches that permitted the evolutionary "explosion" of mammals and, ultimately, human civilization (see *The Planetary Report*, July/August 1983). What theory touches so many of the current threads of modern science? It strikes at the core of current debates on the mechanisms of evolution of species. The hypothesis raises new questions about the constancy and stability of our environment. It involves the discovery, by planetary science, that our own world could not have been spared the sporadic but calamitous impacts recorded by craters on other planets and satellites from Mercury out to the icy moons of Saturn. And it causes us to pause in our thoughts about the role of our technological civilization: on the one hand, does the postulated catastrophe of 65 million years ago prefigure humankind's destructive potential as our nuclear arsenals grow ever larger? On the other hand, could we employ our new technology to save us in the unlikely event that another errant asteroid should be found on an Earth-bound trajectory? These considerations of ecology, paleontology, meteorology, and space science emanate from a decisive geochemical clue found in certain European clay layers by new quantitative measurement techniques whose application to the earth sciences was fostered by the *Apollo* Moon-landing program.

Scientists from many disciplines have only begun to follow all the leads from the "iridium anomaly" found by Walter Alvarez and his colleagues in those thin deposits of ancient "boundary layer clays" that separate the rocks of the Cretaceous (rich in dinosaur bones) from those of the Tertiary (where dinosaur bones are absent but those of mammals are on the ascent). Whatever the ultimate conclusions, the story of "the asteroid and the dinosaur" is sure to be one case where a planetary science perspective (in this case, concerning the role of asteroidal impact) has profound influence on seemingly unrelated sciences.

A new popular book, *The Great Extinction* (Doubleday, 1983, $13.95) is fun to read as an example of creative minds striking out in new directions, leading to a mixture of profound insights and careless lack of rigor. The British authors, Michael Allaby and James Lovelock, are generalists rather than specialists; the recent work of Lovelock has included development of the "Gaia hypothesis" for the intertwined relationship between life and the evolution of life-sustaining planetary environments. As an astronomer, I find it regrettable that this new book is so inaccurate in its portrayal of comets, asteroids, meteorites, and other aspects of planetary science. I suspect other specialists may be chagrined as well, especially the majority of dinosaur experts who still reject catastrophe as a model for the extinction of their favorite reptiles.

Nevertheless, the flood of ideas filling this slender volume about how animal species evolve, interact, and die out will necessarily flush out the defenders of traditional explanations (perhaps including the idea I learned as a child that warm-blooded mammals ate dinosaur eggs while the behemoths slept) into more active consideration of alternatives. As scientists think of the numerous ways the dinosaurs *might* have died in the aftermath of the impact, they could stumble on ideas more directly useful to us in dealing with more frequent natural disasters (like Krakatoa or Tunguska) or with understanding the destructive potential of nuclear war. If *The Great Extinction* is scientifically imprecise, it nonetheless provides good food for thought.

Other Mysteries

Allaby and Lovelock offer their book as a scientific "whodunit," although this literary theme is developed only sporadically. To my way of thinking, the search for stardust in meteorites, as told by Roy Lewis and Edward Anders in the August *Scientific American*, is a much more enthralling tale for erstwhile Agatha Christie fans. The scientific gospel on how the solar system formed would have permitted nothing to survive from earlier epochs. But several puzzling clues, aided by what Lewis and Anders call "the right experiments being done for the wrong reasons," have led during the last few years to convincing proof that microscopic bits of pre-solar-system material have survived in certain meteorites. The precise laboratory chemical techniques used to isolate this exotic material are another legacy of the *Apollo* era. Lewis and Anders are optimistic: further research on meteorites will tell us more about the red giants, novae, and supernovae that created the material of which we are made.

The same August issue of *Scientific American* contains an even more readable article on an equally esoteric topic, magnetohydrodynamics, or as the title of the article puts it, "Magnetic Fields in the Cosmos." Chicago physicist Eugene Parker addresses the question of why magnetic fields are associated with objects as diverse as a dense, cold planet and a tenuous, hot galactic disk. He explains that magnetic fields are maintained and enhanced by the dynamo process, involving the complex motions of conducting material—whether a plasma in space or a liquid metal core within a planet. Dynamos do not create magnetic fields out of nothingness, however, and Parker tells us that the ultimate origin of magnetic fields is still a fertile area for speculation and theoretical research.

An important planetary science meeting, held at Cornell University, concerned the natural (as distinct from artificial!) satellites in the solar system. (See the excellent "Satellite Briefing" by Richard Kerr in the July 29, 1983 *Science*.) The satellites meeting was also duly reported by Jonathan Eberhart in *Science News*. For example, in *SN*'s July 16th issue, Eberhart describes the remarkable findings by Dale Cruikshank and others that distant Neptune's large moon Triton may possess another global ocean in the solar system besides Earth's. Truth is still stranger than fiction, and the suggested truth about Triton is that its oceans are of liquid nitrogen, perhaps with continents of frozen methane!

The next major enterprise of NASA's Planetary Exploration Program after *Voyager* is Project *Galileo*, an ambitious mission to giant Jupiter and its retinue of large moons, smaller satellites, rings, and all-encompassing magnetosphere. No two people are better qualified to describe the scientific objectives of *Galileo* than its chief scientist, Torrence Johnson, and its science manager, Clayne Yeates. They teamed up to write the cover story for the August issue of *Sky & Telescope*, complete with well-selected illustrations of the spacecraft, its instruments, and its many-petalled orbital tour around Jupiter. Not a mere repeat of *Voyager*, *Galileo* is equipped with a new generation of instruments and modern microcomputers that promise to return a wealth of fundamental scientific data. This excellent article is must-reading for Planetary Society members unfamiliar with the *Galileo* mission.

Clark R. Chapman is a research scientist at Planetary Science Institute, a division of Science Applications, Inc., in Tucson, Arizona.

WORLD WATCH

by Louis D. Friedman

In the aftermath of the United States' decision to cancel its spacecraft for the International Solar Polar Mission, Europeans were understandably concerned about the commitment of the U.S. to joint space exploration. Collaborative studies between the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) practically came to a halt. Wishing to undo the damage to international cooperation, the National Academy of Sciences and the European Science Foundation appointed a joint committee on potential international planetary missions. Two subcommittees were formed, one for small bodies (comets, asteroids and satellites) and one for the inner planets.

These subcommittees continue to work. The inner planets group is examining sequels to the Venus Radar Mapper, as well as a Mars orbiter mission, and the small bodies subcommittee is looking at comet rendezvous and multiple asteroid rendezvous possibilities, both by ballistic spacecraft and by low-thrust spacecraft. An ion propulsion unit is under development in Germany.

A third subcommittee is considering a proposal for a mission to Saturn and Titan. Recently, ESA proposed an orbiter/probe mission to Saturn, which they dubbed *Cassini* after the astronomer who discovered the division in Saturn's rings named after him. The original European proposal was for them to build an orbiter and for the U.S. to build a probe based on the Jupiter probe designed for *Galileo*. After *Galileo* was switched to a Shuttle/*Centaur* launch, an untried combination, the project staff recommended that a spare orbiter be built.

NASA advisors and the project personnel then thought of another use for the spare orbiter; if everything went well with the Jupiter launch, the spare could go to Saturn. They recommended to the Europeans an alternative plan whereby the U.S. would build the orbiter and the Europeans, using French missile technology, would design and build a small probe for Titan. This mission would capture popular interest and meet scientists' desire to sample Titan's atmosphere and probe its surface. In addition, the orbiter could map Titan by radar during its repeated close approaches to the mysterious Saturnian moon. This proposal has a financial advantage: A Saturn orbiter/Titan probe was previously estimated to cost between $750 million and $1 billion, and it could now be accomplished for about half that amount. The next *Planetary Report* will be a special issue on Titan.

MOSCOW: In our last issue we reported that the Soviet Union had launched two spacecraft to Venus. The spacecraft, announced as orbiters carrying some East German instruments but no landers, are expected to arrive in early October. Speculation continues that they could be radar mappers.

In March, I discussed Soviet interest in Venus with Dr. Yu. A. Surkov of the Vernadsky Institute for Geochemistry and Analytical Chemistry of the Soviet Academy of Science. This institute is responsible for geochemical experiments on the *Venera* spacecraft. Surkov told me that the next descent vehicle would be the first to land on a highlands region, and at night—eliminating the possibility of pictures. He felt that a highlands landing was important because these regions are analogs to Earth's continents, and there is much to be learned by comparing Venus and the Earth. However, Surkov indicated this landing would be a goal of the 1984 VEGA (Venus-Halley's Comet) mission, and so the mystery about the 1983 mission remains. He also mentioned that VEGA would have small balloons to carry instruments through the Venus atmosphere.

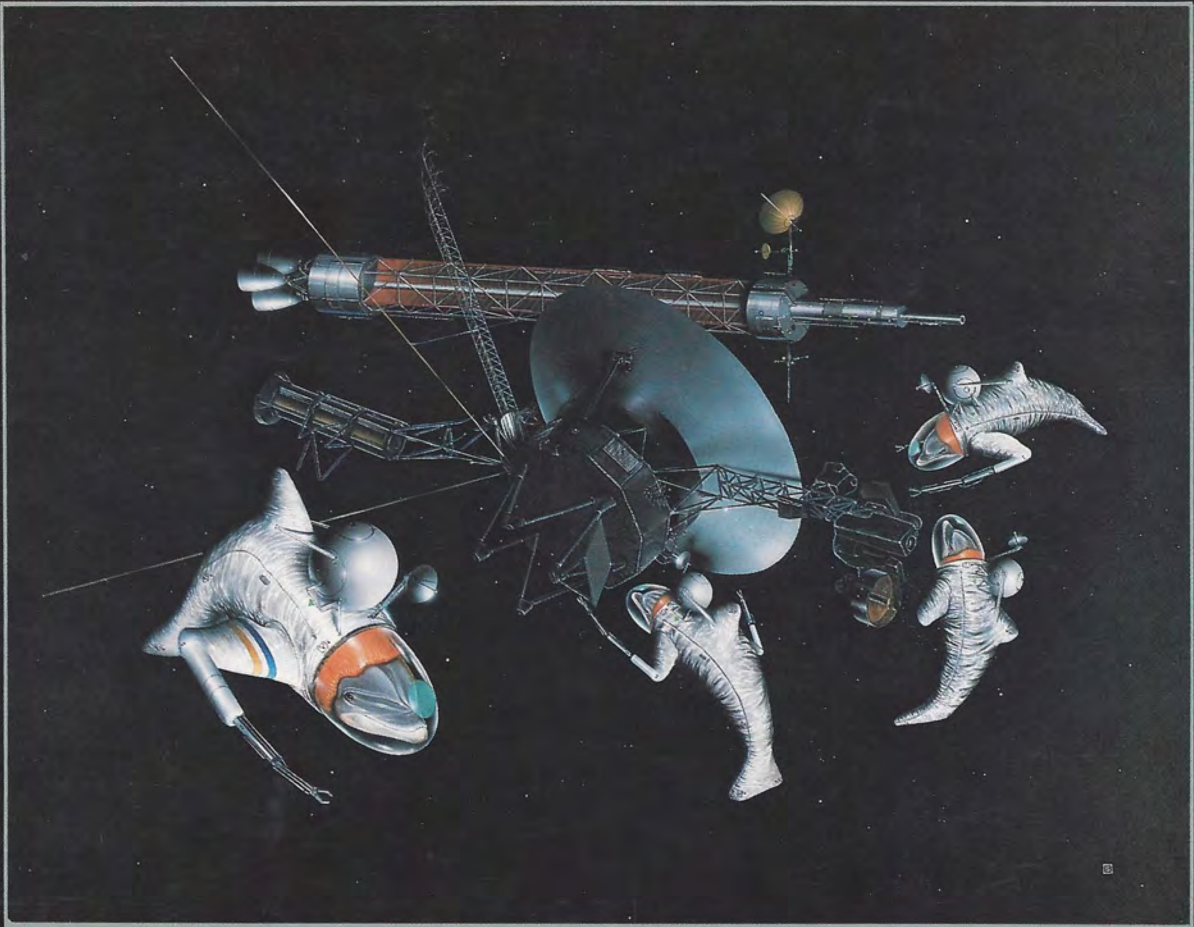
As for future missions by the U.S.S.R., Surkov cited Soviet studies of a lunar geochemical orbiter, a 1990 Venus lander which would be able to "hop" around the planet, and Mars landers.

WASHINGTON: NASA is preparing its fiscal year 1985 budget for the Office of Management and Budget (OMB). This begins a long process, starting in the fall of 1983 with review by the OMB and leading to the President's submission of the 1985 budget following his State of the Union message in late January, 1984. The budget will then be reviewed by Congress.

We expect that in 1985 and 1986 Congress will give serious attention to the space policy of the United States. NASA is expected to ask for a new start on a space station and President Reagan has proposed the development of weapons in space. Both of these proposals will require Congress to come to grips with an issue it has been unable to face since Project *Apollo:* What are U.S. goals for its space program? Dr. George Keyworth, the President's Science Advisor, has already started the debate. Many eyebrows were raised when he recently called on NASA to consider a lunar base or a human mission to Mars. Keyworth had earlier stated his concern that no one had been able to define a use for the space station (see the May/June 1982 issue of *The Planetary Report*). He now feels that if NASA can define its long range objectives, the rationale for the station might become clearer—or it might be found to be weak. Dr. Keyworth also hinted that the Reagan administration might be willing to consider major civil space initiatives for the U.S. (He has already supported the administration's military initiative for space weapons systems.)

The fiscal year 1985 budget will also contain the first of the Solar System Exploration Committee's recommendations: the Planetary Observer series (see the May/June 1983 *Planetary Report*). The Observers are planned as modest missions, mostly to the inner planets or small bodies, conducting special-purpose experiments. The spacecraft will derive from Earth-applications spacecraft and the missions will cost less than previous planetary ventures. The idea is to maintain a steady base with smaller missions, not ruling out later major exploratory missions. The first mission in the Planetary Observer series is a Mars polar orbiter which will examine the red planet for surface or subsurface water. This, of course, is important in planning future Mars exploration. A fiscal year 1985 start on the Mars orbiter will enable a launch in either 1988 or 1990.

The full report of the Solar System Exploration Committee, covering its work to date, is available from the Government Printing Office for $7.00. The summary report is available by using the order form in this magazine. □



VOYAGER FOUND—In this whimsical painting, a fusion-powered spacecraft (background) with a human and dolphin crew has flown 375 billion kilometers out from Earth in pursuit of Voyager 1. The spacesuited dolphins have examined the ancient machine and discovered its phonograph record is missing—someone has been there before them....

Astronomical artist Rick Sternbach, well-known for his illustrations of space hardware, is now working on several book, magazine and film projects. He recently formed Pangaea Productions with fellow artist Don Dixon and is now at work with author G. Harry Stine on a handbook for space colonists.

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