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Mariner 2 Anniversary Issue

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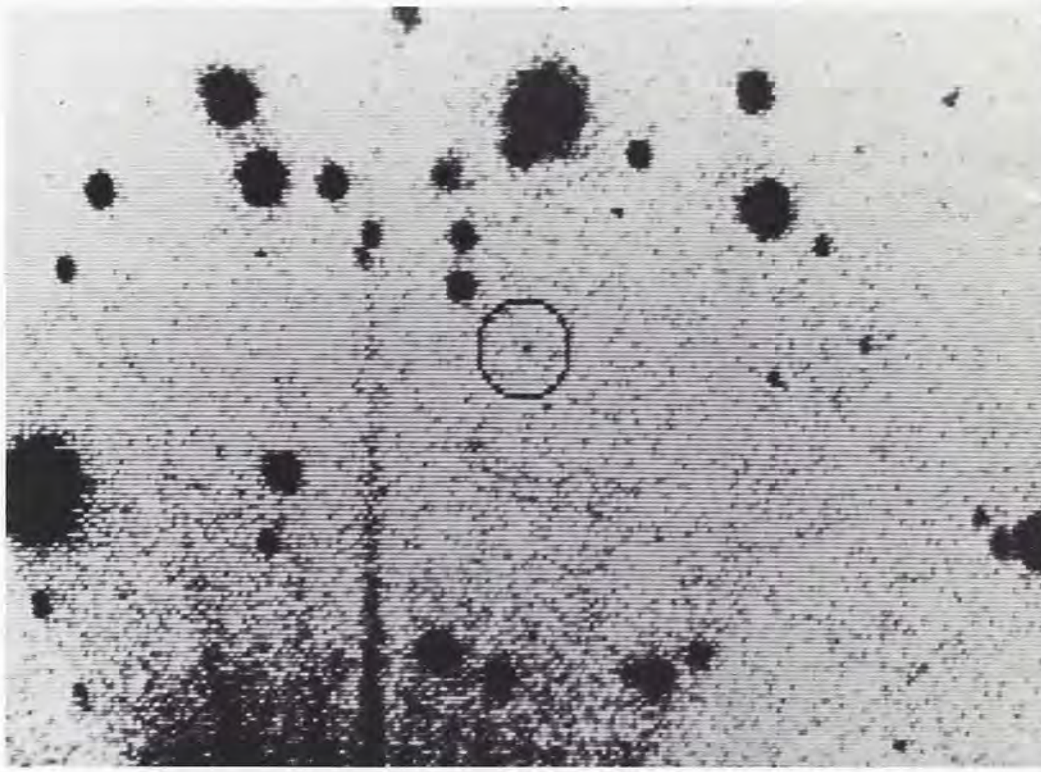
Cover: This computer-generated view of Venus shows the planet's topography, with the highest regions coded as red and the lowest as dark blue. The radar of the Pioneer Venus Orbiter provided the altimetry data from which this image was generated, and can also detect small-scale surface roughness. Rougher areas are coded as a white glint on this picture.
Image courtesy of:
Drs. James Blinn and Walter Brown, JPL



NEWS BULLETIN

HALLEY'S COMET RECOVERED—The race to find Halley's Comet has been won by a team of astronomers at the California Institute of Technology. For the last several months astronomers around the world have been training their telescopes toward the constellation Canis Minor, where the famous periodic comet had been predicted to appear. The Caltech team, led by graduate student David C. Jewitt and staff member G. Edward Danielson, found the comet on October 16, 1982, and verified their observations on October 19.

At its current distance of some 11 astronomical units (one AU is the distance from the Earth to the Sun, about 150 million kilometers), Halley's Comet is approximately 50 million times too faint to be seen with the unaided eye. The Caltech team used the five-meter Hale telescope at the Palomar Observatory in combination with the PFUEI (pronounced "phooey"), the Prime Focus Universal Extragalactic Instrument developed for the Space Telescope. This unit consists of an array of supersensitive electronic light detectors called charge coupled devices, or CCD's. Such an instrument is far more sensitive to light than the photographic plates ordinarily used by astronomers.

The comet was so faint that the glare from a nearby star (visible in bottom of this photo) could have overwhelmed it. The astronomers "masked out" the starlight and were able to record the movement of the comet in six frames taken on October 16. On the 19th, they again photographed the comet and it had moved significantly from its previous position. The comet's observed motion corresponds closely to the positions that had been predicted for Halley's Comet. This close correspondence convinced the Caltech astronomers that they had indeed recovered the famous comet.

Now that the comet has been found, the International Halley Watch will go into action. This umbrella group will organize and coordinate professional and amateur observations of Halley's Comet so that the greatest possible amount of scientific information can be gleaned from this apparition of our visitor.

The 20th Anniversary of Mariner 2

by Carl Sagan

Just 20 years ago, on December 14, 1962, the first successful interplanetary spacecraft launched by the human species reached the vicinity of Venus. It was called *Mariner 2*, and is the ancestor of the long line of historic *Mariner* missions, including *Mariners 5* and *10* to Venus and Mercury, and *Mariner 9* to Mars, the first spacecraft to orbit another planet. The hereditary line that started with *Mariner 2* extends also to the *Viking* and *Voyager* missions.

Mariner 2 was the first spacecraft to measure the solar wind (whose existence had been hypothesized from such arcana as the acceleration of knots in the tails of comets); the spacecraft was immersed in this stream of charged particles pouring out of the Sun at around 400 kilometers per second, and measured directly the proton number density and energy spectrum. *Mariner 2* performed infrared observations of the clouds of Venus. And, by discovering the microwave limb darkening of Venus (see page 8), it provided compelling evidence that the surface of Venus was, by terrestrial standards, absurdly hot. *Mariner 2* gave us a glimpse of what interplanetary robots could do.

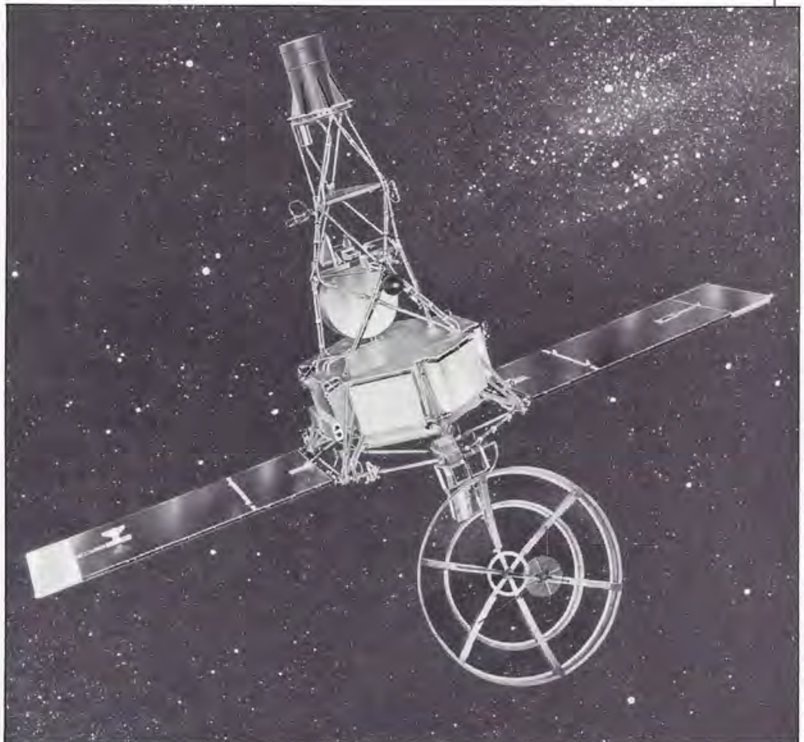
The end of 1982 is another anniversary, 25 years after the launching of the first artificial satellite by the human species—*Sputnik 1*, which made its first circumnavigation of the Earth in 96 minutes on October 4, 1957. The Soviet spacecraft confirmed experimentally what had been known since the time of Newton: that an object traveling laterally, a little above the Earth's surface at a speed of some 28,000 kilometers per hour, would fall forever towards the Earth but never reach it, in a circular or elliptical trajectory. As well it should have, *Sputnik 1* electrified the world, and ushered in the age of space—an epoch of human history which, unless we are so foolish as to destroy ourselves, is likely never to end. One of *Sputnik*'s subsidiary benefits, for which all Americans should be grateful, was prodding the United States into taking science education seriously, an influence that was felt powerfully for ten or fifteen years, before the present precipitous decline.

After more than a thousand orbits of the Earth, *Sputnik 1*, its orbit decaying because of the drag of the thin upper atmosphere of the Earth, disintegrated on January 4, 1958. Its constituent atoms, mainly ablated off the spacecraft during entry, were circulated over much of the Earth before they floated down to the ground. In the death ceremony of the first artificial satellite, its ashes were strewn over much of its planet of origin.

Mariner 2, on the other hand, is still in orbit around the Sun, still approaching, more or less tangentially, the orbit of Venus every few hundred days. When that happens, Venus is almost never there. But if we wait long enough, perhaps hundreds of thousands of years, Venus will be nearby and *Mariner 2* will be accelerated into some completely different orbit. Ultimately, *Mariner 2* will be swept up by another planet, fall into the Sun, or be ejected from the solar system by such gravitational interactions.

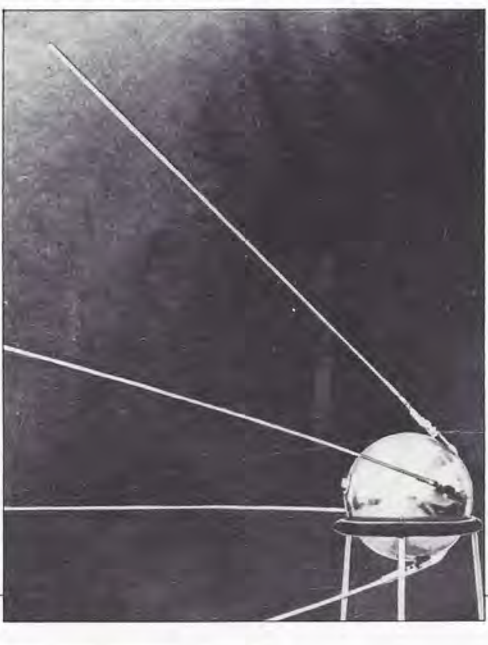
Until then, this harbinger of the age of planetary exploration, this artificial planet, will continue orbiting the Sun in the inner solar system. It is a little as if Columbus' flagship, the *Santa Maria*, were still making regular runs with a ghostly crew across the Atlantic from Cadiz to Hispañola. In the vacuum of interplanetary space, *Mariner 2* will be well-preserved. Perhaps later in the next century some vast ship, on its regular gravity-assisted trajectory to the outer solar system, will intercept this ancient derelict and heave it aboard, ultimately to transport it to a museum of early space technology on Earth or some other nearby world.

Carl Sagan, President of The Planetary Society, was one of the scientific experimenters on the Mariner 2 *mission to Venus.*



***Mariner 2* (above) was the first spacecraft to reach another planet and relay information back to Earth.** PHOTO: JPL/NASA

***Sputnik 1* (below) was the first artificial object to orbit the Earth; the Space Age began with its launch.** PHOTO: SOVFOTO



Remembering Mariner 2

by J. N. James

John F. Kennedy was President and there was a Camelot feeling that better things were going to happen. Elvis provided the music of the times at Cape Canaveral. They called it Cape "Carnival" then, due to the national humiliation of a succession of American space failures and Soviet triumphs. The Soviets had performed the first successful Earth-orbital unmanned and manned flights with *Sputnik 1* and *Vostok 1*. The American failures were beginning to be overcome by our successes with *Explorer 1* and *Friendship 7*, but we were always a step behind the Soviets. Officially there was no race in space, but there was.

The Jet Propulsion Laboratory had been transferred from the Army to NASA as a consequence of the 1958 Space Act. NASA assigned JPL to carry out unmanned lunar and planetary exploration. Two program offices were formed, one lunar and one planetary. I had been working as Bob Parks' deputy on JPL's *Sergeant* project, and when we finished the development of the *Sergeant* missile system for the Army in 1960, we converted our office to manage JPL's Planetary Program. I volunteered to manage the first mission to Venus, which was to be launched by the "yet-to-be-flown" *Atlas-Centaur*. JPL began to develop a spacecraft that weighed some 1000 pounds to match the specified *Atlas-Centaur* capability. At the same time, JPL's Lunar Program office was suffering a series of failures in its *Atlas-Agena*-based *Ranger* project.

In the summer of 1961, with a year to go until the 1962 Venus launch window, NASA announced that the *Centaur* would not be ready in time for the Venus launch. Most of our work had to be scrapped and we embarked upon three weeks of preliminary design and replanning to determine if a less ambitious *Atlas-Agena*-based mission could be salvaged. We came up with a design for a spacecraft weighing about 450 pounds, which included many experiments that had been originally planned for the larger design. [Carl Sagan and Marcia Neugebauer were two of the principal scientists for this mission. See pages 8 and 11.] The key issue was "doability." After all, we were now only 11 months from the beginning of the launch window. Could we design, procure, fabricate, integrate, qualify and launch a spacecraft in the remaining 11 months? We were particularly concerned about our ability to develop, on schedule, the mid-course correction system to get into the target zone near Venus.

I consulted Dr. Homer Joe Stewart, Professor of Aeronautics at the California Institute of Technology. He advised me that by using the *Atlas-Agena* alone to inject the spacecraft into a planetary trajectory without a subsequent maneuver correction, we would have a very small chance of getting close enough to Venus to measure the magnetic field and to make limb sounding measurements for temperatures. The only value to the flight without a midcourse maneuver would be publicity, not scientific gain.

I took the design, along with a hastily drawn program plan and a cost estimate that Fran Fairfield and I had put together literally overnight, and met Bob Parks in Washington to present the plan to NASA. In those days, NASA did not yet have its own building and was housed in the Dolley Madison House.

Bob and I met with Bob Seamans, Abe Silverstein, Ed Cortright, Oran Nicks, Fred Kochendorfer – who was later to be our *Mariner* Headquarters manager – and one or two other NASA Headquarters people to discuss the plan. During the discussion I mentioned our doubts as to our ability to develop the midcourse correction system in time. Abe Silverstein, then Director of Space Flight Programs at NASA Headquarters, said that without a midcourse correction there could be no mission. I answered, "You will have a midcourse correction system." Abe replied, "Then you've got a mission. Go into the conference room and work out your funding needs with my staff."

Bob Parks and I found ourselves surrounded by staffers challenging the cost estimate and probing our expenditures on the *Atlas-Centaur*-based *Mariner* development. After this had gone on for a while, I saw Abe Silverstein listening at the entrance of the conference room, with no tie, his sleeves rolled up and arms folded. (There was no air conditioning in the Dolley Madision House in midsummer 1961.) After listening a while, Abe interrupted the interrogation and said: "Hold it. The amount of funds that these two JPL'ers are asking for to carry out this mission is in the noise of the NASA budget. They are faced with a virtually impossible job. Let's give them the money and let them get to work."

Over the years, Abe has been viewed as a bit of an adversary of JPL's way of doing things, but for his backing at this critical time, I will always be grateful. To take on a job like this we needed help, not harassment, and we couldn't have been given a better send-off.

So the job got underway. There wasn't time to ask JPL's technical divisions how much money they needed to do the job. Fran and I estimated their requirements and gave them their allotted budgets in sealed envelopes.

I selected people for my staff whom I had worked with over the years like Bill Collier, Dan Schneiderman, Tom Bilbo, Nick Renzetti and Milt Goldfine, and they in turn selected 200 more people that I wish I had space to mention here. My staff were people who communicated well with each other. We needed to say something only once and we knew it would be understood, would be done, and would not have to be followed up.

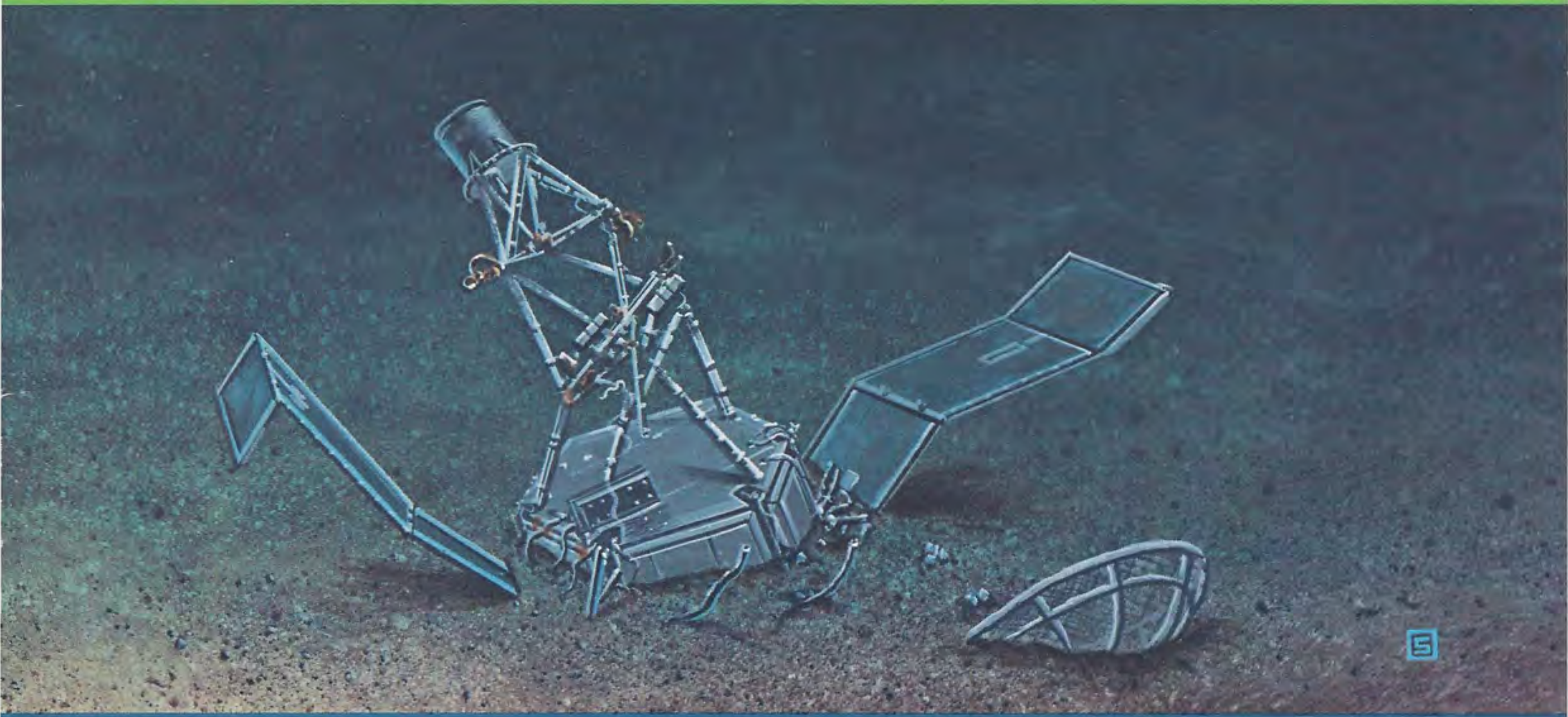
One facet of my plan was to prepare to launch two spacecraft; I wanted redundancy. Back while developing the *Sergeant* system for the Army, I had been the Project Manager on the first fully-guided engineering-model flights. Instinctively, I had prepared two missiles for launch at White Sands. The first missile launched was performing well when it was inadvertently destroyed due to an error by the range safety officer. The second vehicle was launched and also performed well, and this time the mission was completed without human intervention. With this background, I was determined to go into JPL's planetary exploration program with back-up capabilities, and two identical spacecraft began to take form in JPL's assembly facilities.

During those days, displays of national chauvinism on American space missions were discouraged, the spirit of the U.S. Space Act being that our scientific investigations were for the benefit of everyone. I agreed with the Space Act but nevertheless drove into Pasadena and purchased some American flags out-of-pocket. Don Lewis, one of the spacecraft designers, incorporated them into each spacecraft structure.

The way the combined JPL staff, the scientists, Air Force Space Division, Marshall Space Flight Center, General Dynamics/Astronautics, Lockheed Missile and Space Company, and the industrial support team responded to the effort was impressive. Everyone sensed the challenge and became highly motivated to do this almost impossible job.

I was not too helpful to Chris Clausen and Frank Colella of JPL's Public Information staff until we had completed shipment of both spacecraft to the Cape. I had told the team members that no one was qualified to give speeches or press releases on the mis-

PAINTING BY RICK STERNBACH



For Want of a Hyphen, a Spacecraft Was Lost....

In the midst of commemorating the first successful flight of a spacecraft—Mariner 2—to another planet, it is natural to ask, "Whatever happened to Mariner 1?" Mariner 1 lies at the bottom of the Atlantic Ocean, a piece of jetsam. The rocket carrying the spacecraft went off course during launch and was destroyed by the range safety officer at Cape Canaveral.

What went wrong? That question was asked again and again in the weeks following the July 22, 1962 destruction of Mariner 1, and the answer was finally traced to a programmer who, when feeding a guidance equation into a computer, somehow lost a hyphen, or "bar," above the element R.

The bar had been missing for the first several flights of the Atlas rocket, but it had not affected its performance because all other guidance systems were performing properly. But on Mariner 1's Atlas, the antenna performed below specifications so that the guidance signal received by the rocket was weak and noisy. This faulty antenna, combined with the changing flight path and ionized exhaust from the engines, caused the rocket to lose its lock on the ground guidance link. The ground computer was programmed to search for the vehicle's radio beacon and reestablish contact. But while this search was going on, the Atlas' computer was supposed to reject information from the search and accept command information only when lock was reestablished. The command for this was $\bar{R}$.

Without this command in its guidance equation, the rocket responded to the beacon search, turned left, and then nosed down. At that point, the range safety officer pushed the destruct button. The rocket blew apart and what was left of Mariner 1 sank to the bottom of the Atlantic.

sion except team members, and that any team member who had time to make a speech didn't understand what we were up against. But after we arrived at the Cape, and throughout the difficult mission, Frank and Chris were key *Mariner* team members.

Cliff Cummings and Jim Burke, JPL's Lunar and *Ranger* Project Managers, had suffered a succession of early failures, but they were helpful to us. They quickly introduced my team to the *Atlas-Agena* community and provided us with applicable *Ranger* parts and design. We shared the notion that, in those days, a Project Manager was "only a transistor away from being a hero or a victim." The U.S. *Mariner* to Venus in 1962 could not have been accomplished without their precursor efforts on the *Ranger* project. In fact, many will recall that this particular *Mariner* design was called Model "R" for its considerable *Ranger* inheritance.

As the development proceeded, I had to institute a procedure with my management staff. Since we communicated status and progress at all times of the day and night, I asked that the first words in any conversation over the telephone were to be either "there is no problem" or "we have a serious problem." My nerves could not accept the suspense of a preamble before knowing where we stood.

Finally, the systems all came together and we shipped them to the Cape in June, 1962.

Just to make things sportier, the aircraft that normally transported the *Atlas* to the Cape were all grounded due to a crack in a wing spar. For the first time in years, the *Atlas* had to be transported by surface. This involved routing the truck to avoid the many low underpasses around the nation. Also, I was assured that an *Atlas* had yet to be transported across the back roads of the country without some young farm lad putting at least one .22 caliber bullet hole in it.

After getting all elements of the space system in transit, my wife Ruth, four children, mother, father and I, along with the rest of the *Mariner* flight team, packed off to the Cape for the weeks of preparation.

On the night of July 21, 1962, *Mariner 1* was ready to launch. As Jim von der Wische of General Dynamics and I stood outside the Block House he said, "It looks just like a new engagement ring, doesn't it?" He was referring, of course, to the results of our work. The clean lines of the entire space system were well-illuminated by spotlights, and it was poised for takeoff with the gantry rolled back.

Mariner 1 was a failure. I couldn't believe that it could happen to me again as it had happened on *Sergeant*, but the spacecraft was destroyed by the Atlantic missile range officer — this time with justification. Two failures, a below-specification guidance antenna and a symbol in the guidance equations, which had been missing for several *Atlas-Agena* flights, worked together to cause the *Atlas* to oscillate in its flight path. The range safety officer decided to send a destruct signal.

After making a preliminary failure analysis and responding to the press throughout the night, it was a lonely ride to our apartment on Cocoa Beach. On the way back, I was compelled to listen to the news broadcasts of the failure on my car radio. They were separated by the occasional playing of Ray Charles' version of "Born to Lose," which didn't cheer me up. When I arrived at the apartment, the bottle of champagne that my wife and I had saved for the occasion seemed very much out of place.

Because we needed three weeks between launches, only one month remained before Venus moved out of range. During that time we had to analyze the failure and correct the problems while preparing the next space system for launch. Frank Colella commented that I was pretty cheerful considering what had happened. I told him it was because we had another chance.

The problems were corrected and, as the night of the launch of *Mariner 2* approached, Dr. William H. Pickering, then Director of JPL, surmised that I could use a little support. He asked retired Army General Bruce Medaris to join me at the Cape and to give me any advice that I might need. I welcomed the presence of the General. He was the fine manager of the Army Ballistic Missile Agency that had helped us put up *Explorer 1*, the first successful American satellite. But it wasn't only his experience that I wished to benefit from. General Medaris, upon his retirement, had contracted cancer and recovered from it. To show his gratitude, he became an ordained minister. I thought that he might be able to obtain some Divine assistance, which we sorely needed, given the destruction of a perfectly good *Mariner 1* spacecraft.

Once again, we relived preparation and launch. *Mariner 2* was launched at 0600 hours, 53 minutes, and 13.927 seconds Greenwich Mean Time on August 27, 1962.

Shortly after launch, Colonel H. H. Eichel and Major (later Lieutenant General) Jack Albert from the Air Force Space Division visited me in the Control Center and said, "Jack, we don't know how you got there, but you are on your way to Venus." They were incredulous because a short in the guidance system had caused the *Atlas* to start spinning at a rate of one revolution per second. The short had miraculously corrected itself within tenths of a degree of the proper position of the roll gyros on the 36th revolution. This allowed control to be reestablished in time for a good planetary trajectory injection by the *Atlas-Agena* combination. Dan Schneiderman, my spacecraft system manager, commented that it simply had to work because every member of the team was "willing" it to lift off and to perform successfully. This was the first of several failures that happily were to be self-correcting. Some of these follow, as copied from the log of *Mariner 2*.

L + 2 days: Cruise science instruments are commanded on from the NASA/JPL Johannesburg Deep Space Station. The critical Earth sensor begins to show higher than normal temperatures.

L + 8 days: The midcourse correction maneuver is successfully performed with a declining Earth sensor signal after maneuver commands are transmitted from the Goldstone Station in California.

L + 15 days: Earth sensor signals continue to fall, the forecast being that within a few days the spacecraft will lose control. A leak had developed between the nitrogen supply and the fuel tank. The spacecraft goes momentarily unstable due to an impact from space debris or due to a stuck control jet.

L + 33 days: The Earth sensor sensitivity, which had declined almost to the point of causing the loss of all spacecraft control, inexplicably recovers to a normal signal level.

L + 56 days: Halfway point to Venus.

L + 65 days: A major failure, probably a short, occurs in one solar panel. *Mariner 2*, however, is now close enough to the Sun to operate successfully on its remaining panel.

L + 72 days: The failed solar panel repairs itself.

L + 79 days: The same solar panel repeats its failure. No problem: *Mariner 2* is even closer to the Sun.

L + 92 days: The deep space communication record is established at 17 million miles. All spacecraft units are much hotter than expected and the temperature control system has reached its limit. At its temperature the Earth sensor should have lost all sensitivity, but it continues to work well.

L + 108 days: On December 14, 1962, the on-board programmer failed to turn on the close encounter science, but the science is successfully commanded on by a signal from the Goldstone Station. The radiometer for measuring the temperature of Venus begins to slowly scan the planet. Fortunately, it goes into a fast scan mode at just the appropriate time to scan the shady side, the terminator and the sunny side of Venus.

L+ 129 days: Twenty-one days after the encounter, communication between *Mariner 2* and the Deep Space Station at Johannesburg ceases. We really never knew why, but *Mariner 2* was never heard from again.

I thanked as many of the team members as I could. While doing so, I mentioned to Homer Joe Stewart that we had been a bit lucky. His reply to me was that you have to be very close to right in order to be lucky.

The first successful mission to a planet had been completed and my wife and I finally had that bottle of champagne.

J. N. James has held a succession of senior management positions at JPL. He is currently the Assistant Laboratory Director for Defense Programs.

Mariner 2

by [illegible]

Compared to the *Voyager* or *Viking* spacecraft, *Mariner 2* was a very simple, even primitive, device. But twenty years ago the successful flight of *Mariner 2* to Venus was a major milestone in the development of space exploration.

Mariner 2 was the first human-made object to travel from Earth to the vicinity of another planet and relay back to Earth the observations made by its instruments. The Soviet Union had attempted such a mission before *Mariner 2*, but without success. For the first time, the United States achieved a major success before the Soviets did.

Not only was *Mariner 2* an important mission for the U.S. and for NASA, but it was also vital to the development of the Jet Propulsion Laboratory. At that time JPL was still establishing its role within NASA. It had been assigned the *Ranger* missions to the Moon. Four *Rangers* had been launched prior to *Mariner 2* and none had been completely successful. In fact, during the flight of *Mariner 2*, *Ranger 5* was launched and failed shortly after separation from the launching rocket. *Ranger* was in deep trouble. NASA appointed the Kelley Board to review the project. Concern was expressed in Congressional and other circles about the ability of JPL to conduct space projects. The successful flight of *Mariner 2*, however, helped dissipate this concern, and raised the morale of the JPL team. *Mariner* was a close relative of *Ranger* and the flight demonstrated that the basic design concepts were sound.

The flight of *Mariner 2* in 1962 was the first step towards making us really aware that the Sun and its planets are all in our immediate cosmic neighborhood. For the first time, we had left the family home and visited our next-door neighbor.

Dr. William H. Pickering was Director of the Jet Propulsion Laboratory from 1954 to 1976, and under his leadership JPL moved to the forefront of planetary exploration. Here, he remembers the flight of Mariner 2, *the first successful mission to another planet.*

The Race to Venus and Mars

by James D. Burke

It was good, clean, and bold. In the 1960's American and Soviet enthusiasts engaged in a planetary contest almost as exciting as the Moon race of those same years. The Soviets tried harder, launching more and bigger spacecraft at every Mars and Venus opportunity, but the Americans were more successful. Sour critics may have viewed these lunar and planetary missions as propaganda and indeed, to some extent, they were. But the thoughtful historian Silvio Bedini of the Smithsonian Institution compares the early years of deep-space exploration to the outburst of energy that raised Europe's medieval cathedrals — another great human enterprise driven by a mixture of abstract ideals, competitive civic pride, curiosity, and the simple joys of the craftsman.

The race began in January, 1959 with the Soviet launch of the *Mechta* (Dream), the first lunar probe to escape the gravity of Earth. *Pioneer 4* soon followed, and by the end of the year both nations were planning flights to Venus and Mars.

At first the goal was to launch during the October, 1960 Mars window. In the U.S. this soon proved impractical and American efforts were turned to the July-August 1962 Venus opportunity. The Soviets did launch two Mars vehicles in October, 1960, but both big rockets failed. They tried again at the February, 1961 Venus window. One of those two vehicles sent the first interplanetary spacecraft, *Venera 1*, on its way. Though that spacecraft later failed enroute, it was a mighty spur to the U.S. effort, because it demonstrated some of the features, such as oriented solar panels and parabolic high-gain antenna, that the Americans were planning to use.

The American team began by designing two half-ton spacecraft called *Mariner A* and *B*, for Venus and Mars respectively, to be launched by *Atlas-Centaur*. By August, 1961 it became evident that the *Centaur* could not be ready in time for the 1962 window, so the plan was changed to use a lightweight spacecraft, to be called *Mariner R* because of its derivation from the contemporary *Ranger* Moon probes, that could be launched by *Atlas-Agena*. A frantic eleven months later (see article by Jack James, pages 4–6), *Mariner 1* and *Mariner 2* were in Florida, ready for launch.

Meanwhile, the Soviets had been preparing an unprecedented series of explorations of Venus and Mars. The launch record in 1962 was:

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22 July — American *Mariner 1* to Venus, launch failed.

25 August — Soviet Venus spacecraft, launch failed.

26 August — American *Mariner 2* to Venus, launch success.

1 September — Soviet Venus spacecraft, launch failed.

12 September — Soviet Venus spacecraft, launch failed.

24 October — Soviet Mars spacecraft, launch failed.

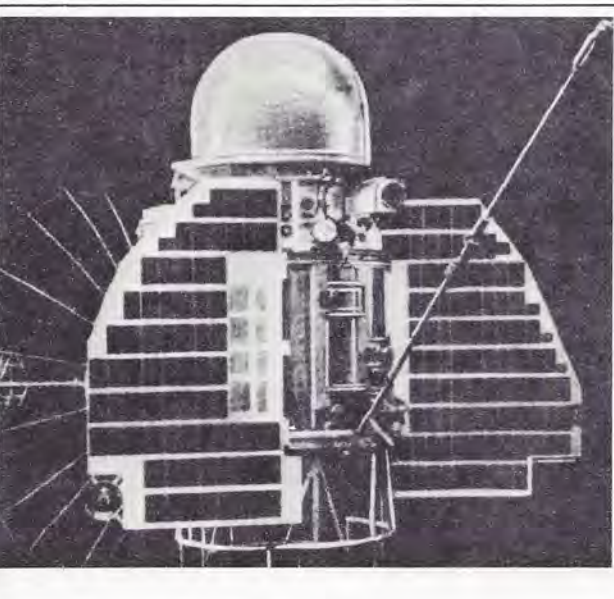
1 November — Soviet *Mars 1*, launch success.

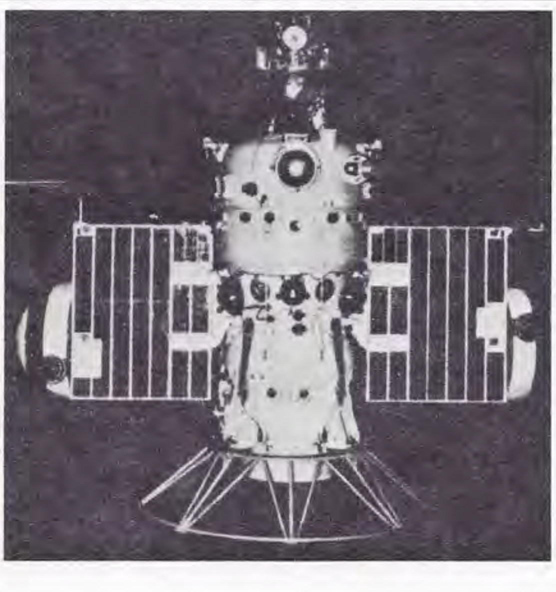
4 November — Soviet Mars spacecraft, launch failed.

Mars 1, the sole survivor of the six Soviet launches, operated in interplanetary space for several months, long enough to have made it to Venus but not long enough for the trip to Mars. It represented the next generation of Soviet spacecraft, the type that finally, in 1967, sent back data from inside the atmosphere of Venus.

Looking back from today, with two decades of experience to show us how arduous and demanding planetary exploration really is, the frenzy of 1962 seems bold to the point of foolhardiness. But later successes, both American and Soviet, have made it all worthwhile. Those were the years when each nation quickly put its finest technical abilities on the line, win or lose, in a contest that threatened no one, opened our scientific horizons to new worlds, and gave us a glimpse, despite our differences on Earth, of what our future could be. Now both programs have become highly successful, other nations have entered the field, and the symbolic importance of the U.S.-Soviet space race has declined. Nevertheless, those early, all-out strivings have left their mark on a generation of engineers and scientists in the U.S. and U.S.S.R. — people who may yet influence the course of events between the two main technical nations of Earth. It is a fragile legacy, easily forgotten amid nuclear threat and counter threat, but it does indeed survive.

James D. Burke, our Technical Editor, manages advanced astrophysics studies at JPL. He was the Ranger *Project Manager from 1960–62 and since then has been involved in a number of JPL deep space projects and pre-project studies.*





***Venera 1* (far left) was the first human artifact launched toward Venus. With oriented solar panels and a high-gain antenna, it foreshadowed all other interplanetary spacecraft. *Venera 1* failed enroute to the vicinity of Venus.**

***Mars 1* (near left) was the first human artifact launched toward Mars. Larger and more complex than *Venera 1*, it was the first of the generation of Soviet craft that later delivered probes to the surface of Venus. *Mars 1* failed enroute to the vicinity of Mars.**

PHOTOS: JPL/NASA

How We Discovered

by Carl Sagan

Venus has long been thought of as our sister world. It is the nearest planet to the Earth. It has almost the same mass, size, density and gravitational pull as the Earth does. It's a little closer to the Sun than the Earth, but its bright clouds reflect more sunlight back to space than our clouds do. As a first guess you might very well imagine that, under those unbroken clouds, the surface conditions on Venus would be like those of Earth. Early scientific speculation about Venus included images of fetid swamps crawling with monster amphibians, like the Earth in the Carboniferous; or a world covered with a seltzer ocean (because of the large abundance of carbon dioxide in the Venus atmosphere), and dotted here and there with carbonate-encrusted islands. While based on some scientific data, these "models" of Venus – dating respectively from the beginning of the century and from the mid-1950's – were little more than scientific romances, only loosely constrained by the sparse available data.

FIGURE 1

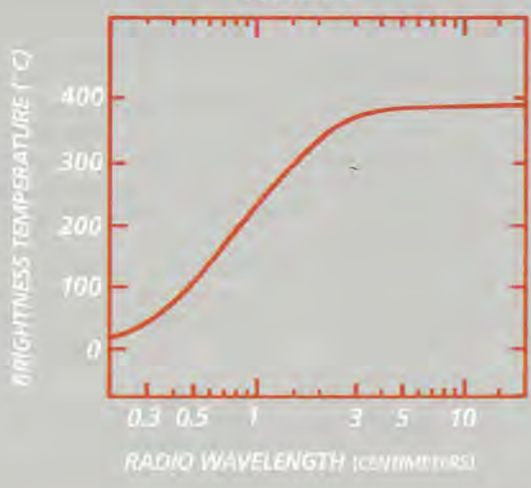


FIGURE 1: ***The radio brightness temperature of Venus, as measured from the Earth, is congenial at short, millimeter wavelengths and broiling at long, centimeter wavelengths. What does this spectrum, available before spacecraft entered the Venus atmosphere, tell us about the real conditions on Venus? The probable error of measurement is several times the thickness of the curve.***

FIGURE 2a: ***Why a hot surface and a cool atmosphere should produce radio limb-darkening.***

FIGURE 2b: ***Why a cool surface and a hot upper atmosphere should produce radio limb-brightening.***

Then, in 1958, a report was published in *The Astrophysical Journal* by Cornell H. Mayer and his colleagues. They had pointed a newly-completed radio telescope built, in part for classified research, on the roof of the Naval Research Laboratory in Washington, D.C., at the planet Venus and measured the flux of radio waves arriving at the Earth. Venus turned out to be considerably brighter than the background of distant stars and galaxies. This in itself was not very surprising. Every object warmer than absolute zero (minus 273° Centigrade) gives off radiation throughout the electromagnetic spectrum, including the radio region. You, for example, emit radio waves at an effective or "brightness" temperature of about 35°C, and if you were in surroundings colder than you are, a sensitive radio telescope could easily detect the radio waves you are transmitting in all directions.

But what *was* surprising about Cornell Mayer's discovery was that the brightness temperature of Venus is more than 300°C, much higher than the surface temperature of the Earth or the measured infrared temperature of the clouds of Venus. It was at least 200° hotter than the normal boiling point of water. What could this finding mean? Very soon, there was a plethora of proposed explanations. I argued that the high radio brightness temperature was a direct indication of a hot surface, and that the high temperatures were due to a massive carbon dioxide/water vapor greenhouse effect – in which some of the visible light from the Sun was transmitted by the clouds and heated the surface, but the surface was experiencing enormous difficulty in radiating back to space because of the high infrared opacity of carbon dioxide and water vapor. Carbon dioxide absorbs at a range of frequencies through the infrared, but there are "windows" between the CO_2 infrared bands through which the surface could readily cool off to space. Water vapor, however, absorbs at infrared frequencies that correspond in part to the windows in the carbon dioxide opacity, and the two gases together, it seemed to me, could pretty well absorb almost all the infrared spectrum, even if there was very little water vapor – something like two picket fences, the slats of one being positioned by accident in the spaces between the slats of the other.

There was another very different category of explanation, in which the high brightness temperature of Venus had nothing to do with the surface. There was, it was proposed, a region in the atmosphere or in the magnetosphere of Venus that emitted radio waves to space. Electrical discharges between liquid water droplets in the Venus clouds were suggested. A glow discharge in which ions and electrons recombined along the twilight and dawn terminators in the upper atmosphere was proposed. A very dense ionosphere had its advocates, in which the mutual acceleration of unbound electrons ("free-free emission") gave off

That Venus is Hot

radio waves (one advocate of this idea even suggested that the high ionization required was due to an average of 10,000 times greater radioactivity on Venus than on Earth — perhaps due to a recent nuclear war there). And, in the light of the discovery of synchrotron radiation from Jupiter, it was natural to suggest that the radio emission came from an immense cloud of charged particles trapped by a putative very intense Venus magnetic field.

In a series of papers published in the middle 1960's, mainly by James B. Pollack (now at NASA's Ames Research Center) and me, these models of a hot high emitting region and a cold surface were subjected to a critical analysis. By then we had two important new clues: the radio spectrum of Venus, and the *Mariner 2* evidence for radio limb-darkening. If you would look at Venus at a given radio frequency you would detect a certain brightness temperature. But at some other frequency, the brightness temperature would be different. This variation of brightness temperature with frequency, or wavelength, is called the radio spectrum of Venus, and it soon became clear that its shape was something like that shown in **Figure 1**: At wavelengths of a few centimeters and longer, Venus emitted radio waves as if it was at a temperature near 400°C. But at wavelengths less than one centimeter — in the millimeter spectrum — the brightness temperature fell toward values deemed congenial by the inhabitants of the Earth.

How was the spectrum to be understood? Those like me who thought that the surface was hot argued that the high brightness temperatures at long wavelengths corresponded to real thermal emission from a hot surface. The lower brightness temperatures towards millimeter wavelengths must then be due to absorption of the surface radio emission by a colder overlying atmosphere. And Alan Barrett of the Massachusetts Institute of Technology had shown that an atmosphere about a hundred times more dense than that at the surface of the Earth and composed mostly of carbon dioxide could explain this fall-off towards shorter wavelengths. How did people who believed that the surface was cold and the hot emitting region high interpret the radio spectrum? They thought that the hot high emitting region was responsible for the 300°C brightness temperatures at long wavelengths, and that the fall-off towards short wavelengths was due to the emitting region becoming transparent, permitting us to begin to see through to the much colder surface beneath.

The critical wavelength to test the difference between these two sets of models was around one centimeter (see **Figure 1**) — the transitional wavelength between high and low temperature regimes in either set of models. Imagine yourself flying above Venus, looking down at the planet beneath you. At visible wavelengths, of course, you see only clouds. But if your eyes were sensitive in the radio part of the spectrum you would see deeper; as you go towards radio wavelengths, the clouds get more and more transparent. In the hot surface model you would see to the surface at long wavelengths; in the cold surface model you would see the surface at short wavelengths. Now imagine yourself scanning from the center of Venus towards the horizon (or limb), with your eyes sensitive at one centimeter wavelength, in the transition region. You will have a longer slant path through the atmosphere when you look at the limb compared to when you look at the center of the disc (**Figure 2a**). If the surface is hot with a cold absorbing layer above it, you will see more cold absorber in your line of sight as you look towards the limb; the brightness temperature should decline from center to limb. This is called "limb-darkening." On the other hand, if the cold surface, high hot emitter model were correct, as you scan from center to limb you would see the brightness temperature increasing, because in this transition region you

FIGURE 2a

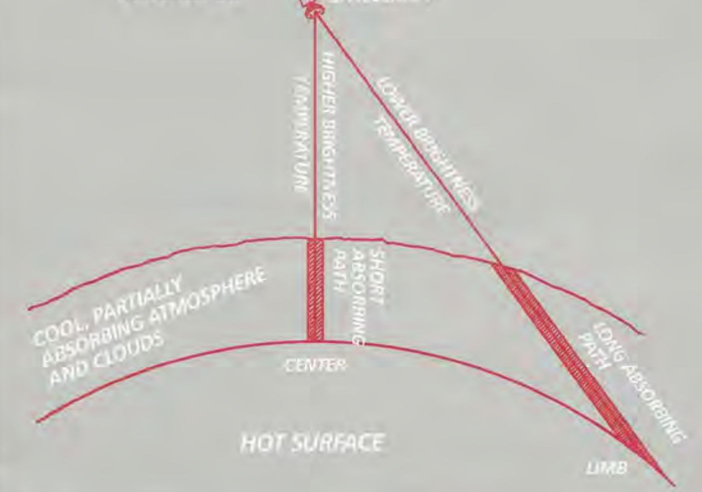
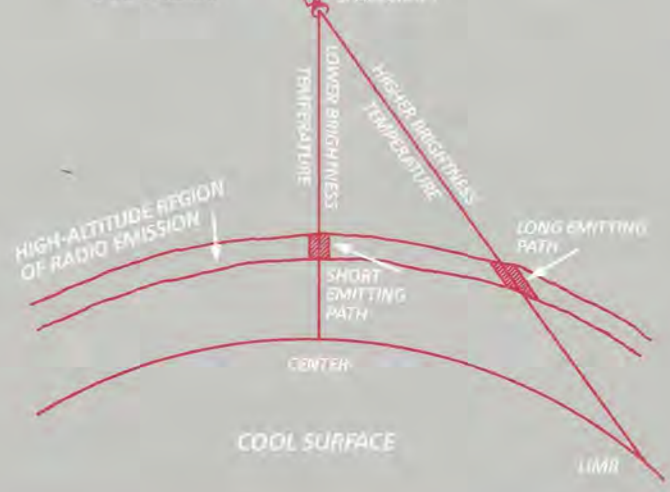


FIGURE 2b



would be seeing a longer path through the hot emitting region at the limb than at the center of the disc (**Figure 2b**). This is called "limb-brightening."

Unfortunately, no single radio telescope on Earth could, in the early 1960's, resolve the disc of Venus, and compare the center with the limb. They could only view a much larger region of sky which contained, as a comparative pinpoint in its center, the disc of Venus. There was then no chance of determining whether Venus showed limb-darkening or limb-brightening at one centimeter if we were restricted to the surface of the Earth. (Nowadays, radio interferometric techniques can do such measurements from the Earth.) So *Mariner 2* was equipped with a small radio telescope which took a series of measurements, at a wavelength of 1.9 centimeters, between the center of the disc and the limb. Even though *Mariner 2* did not come nearly as close to Venus as had been planned, it came close enough for this "microwave radiometer" experiment to provide unambiguous evidence: Near one centimeter wavelength, Venus exhibits limb-darkening. Thus, by 1967, we were able to deduce with some confidence that the surface of Venus was at an unhealthy and un-Earthlike temperature well in excess of 400°C. But the argument was inferential, and there were many intermediate steps. We longed for a more direct measurement.

In October, 1967, the Soviet spacecraft, *Venera 4*, dropped an entry capsule which returned data from the hot lower atmosphere of Venus but not from the surface; and one day later the United States spacecraft, *Mariner 5*, flew by Venus, its radio transmission to Earth skimming the atmosphere at progressively greater depths, and the rate of fading of the signal giving information about atmospheric temperatures. Although there seemed to be some discrepancies (later resolved) between the two sets of spacecraft data, both clearly indicated that the surface of Venus was hot. Since then a progression of Soviet *Venera* spacecraft and one cluster of American *Pioneer*/Venus spacecraft have landed on the surface of Venus and measured directly — essentially by sticking out a thermometer — the surface temperature. It turns out to be about 470°C. When such factors as calibration errors of terrestrial radio telescopes and surface emissivity are taken into account, the old radio observations and the new direct spacecraft measurements turn out to be in good agreement. Thus, this year is not only the 20th anniversary of *Mariner 2*, but also the 15th anniversary of the *Venera 4* and *Mariner 5* missions, which confirmed the high surface temperature of Venus.

The resistance to the idea of a hot surface on Venus was, I believe, due to our reluctance to give up the notion that the nearest planet is a congenial environment for future exploration and perhaps even, in the longer term, for human settlement. As it turns out there are no Carboniferous swamps, no global oceans. Instead, Venus is a stifling, brooding inferno. But it is our job to find out what the universe is really like, not to foist our predispositions upon the universe. And I am confident that human ingenuity will continue to be equal to the task of exploring this broiling, poisonous, astonishing planet which, perhaps predictably, is rich in insights about our own world.

The aspect of this detective story that I find most satisfying is that it was possible, from remote and indirect data and the laws of physics, to deduce correctly essential aspects of the exotic environment of another world. But this would have been much more difficult without the critical information from *Mariner 2* — the ship that ushered in the age of spacecraft planetary exploration.

[A more detailed history of the competing models of the Venus radio emission can be found in Carl Sagan's technical article, "Microwave Radiation from Venus: Thermal versus Non-Thermal Models," *Comments on Astrophysics and Space Physics 1*, 94–100, 1969, and some anecdotes from the early history of spacecraft exploration of Venus are in his book, *The Cosmic Connection: An Extraterrestrial Perspective*, Doubleday, New York, 1973.]

Oceans on Venus? by R. Richard Hodges, Jr.

Because Venus and Earth orbit the Sun near each other, it seems reasonable to suppose that they condensed out of the same region in the solar nebula, and hence should at first have had similar chemical compositions. This view is supported by similarities in planet size and mass, as well as past outgassing which has released on each planet roughly the same amount of carbon dioxide. The key difference is water. Oceans on Earth assimilate carbon dioxide into carbonate deposits, but the dry inert Venus surface does not encourage the formation of carbonates, forcing the accumulation of an extremely dense CO_2 atmosphere.

How can an ocean on Venus, if there ever was one, have vanished? The first step might have been a so-called "runaway greenhouse" event in which the atmosphere became opaque to outgoing infrared radiation, the planet's surface heated up, and the ocean boiled away. During this process, atmospheric water vapor molecules would have been dissociated by solar ultraviolet photons, their oxygen going from the atmosphere into the planet's crust as oxides and most of the hydrogen escaping hydrodynamically in a supersonic expansion to space. Whether or not this early catastrophic greenhouse event occurred, the escape of hydrogen would have continued throughout geologic time, driven by slower exospheric processes that preferentially removed the lighter isotope (H) relative to deuterium (D), the hydrogen of "heavy water." The end result would be an enrichment of D relative to H in the upper atmosphere of Venus, with the D to H ratio an indicator of how much hydrogen had escaped by these slower, mass-differentiating processes.

One of the startling discoveries of the *Pioneer* Venus mission was that the value of D/H is about 0.016, or about 100 times the terrestrial ratio. The present, residual water vapor content of the Venus atmosphere is probably about 200 parts per million, hence the hundredfold enrichment in deuterium corresponds to a gradual loss of hydrogen roughly equivalent to two percent of the present atmosphere. A global ocean with an average depth of about ten meters, or about 0.3 percent of the terrestrial ocean, could have been the origin of this hydrogen. This two percent ratio is just about what would be expected at the end of a runaway greenhouse event.

The present D to H ratio is thus consistent with an early catastrophic event that destroyed vast oceans, and so it supports the theory that Earth and Venus may have been very similar in their early histories. Owing to the high probability that a runaway greenhouse event has occurred on Venus, it may be important to the survival of the present life-supporting environment of the Earth that we gain an understanding of how such events are triggered.

R. Richard Hodges, Jr. is a research scientist at the University of Texas at Dallas. He was a co-investigator for the neutral mass spectrometer experiment on the Pioneer *Venus sounder probe, along with J. H. Hoffman, T. M. Donahue and M. B. McElroy.*

Mariner 2 and the Discovery of the Solar Wind

by Marcia Neugebauer

Marcia Neugebauer examines a Mariner spacecraft. Mariner 2 detected the existence of the solar wind on its flight to Venus. The microwave radiometer dish, discussed on pages 8–10, can be seen in the upper right of this picture. PHOTO: JPL/NASA

The true nature of the solar wind was not experimentally demonstrated until the flight of *Mariner 2*. For several decades scientists had suspected that aurorae and geomagnetic storms were caused by streams of charged particles from the Sun. In the 1950's Ludwig Biermann realized that, since the ion tails of comets always point away from the Sun, these particle streams must continuously fill interplanetary space.

Then, in 1958, Eugene Parker of the University of Chicago published a landmark paper in which he coined the phrase "solar wind" to describe the continuous supersonic expansion of the ionized solar atmosphere. In this paper, Parker pointed out that the pressure of the very hot solar atmosphere is so high that neither the Sun's gravity nor the pressure of the interstellar medium could hold the gas down; it must escape into space at speeds of several hundred kilometers per second. Parker's theory was almost immediately challenged by Joseph Chamberlain, also at the University of Chicago, who claimed that the proper solution to the very complex set of equations used to describe the solar atmosphere would be a subsonic solar breeze, blowing at a mere ten kilometers per second.

Several attempts to measure the solar wind, or breeze, were made between 1959 and 1962. Plasma detectors were carried on three Soviet lunar missions in 1959 and on a *Venera* spacecraft in 1961. With their limited sensitivity, these early instruments detected only occasional fluxes of ions in space and could not measure the ion speed or density. The more advanced instrument on *Explorer 10* detected intermittent streams moving at about 300 kilometers per second. In retrospect, we know that this spacecraft never reached the undisturbed solar wind beyond the Earth's bow shock; the trajectory was nearly parallel to the boundary of the Earth's magnetosphere and the periods when flows were absent corresponded to times when the spacecraft was inside it.

The next attempt was made in August, 1961, with *Ranger 1*, which carried a plasma instrument for which Conway Snyder and I were the investigators. Our launch was even worse. *Ranger 1* never got beyond the ionosphere. We had another try with *Ranger 2* in November, 1961, with the same result. 1961 also saw the successful launch of *Explorer 12*, but its solar wind detector did not function properly and no data were obtained.

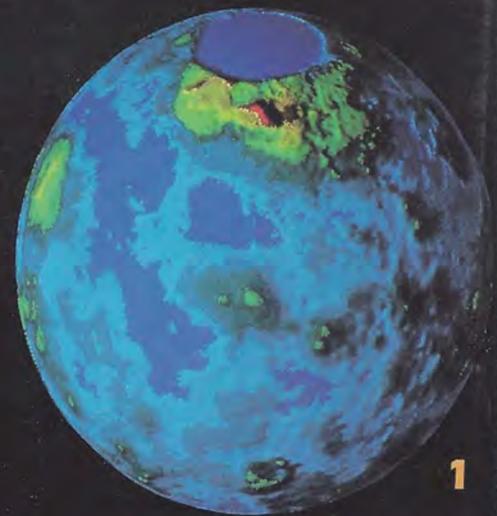
Conway and I then had a chance to fly our third and fourth experiments on *Mariners 1* and *2*. The mass allocation for our *Mariner* experiment was much less than for *Ranger*, forcing us to eliminate five of our six detectors, leaving only the detector which faced the Sun. The theoretical models and the *Explorer 10* data persuaded us that this was probably safe to do – that the only plasma flow would be from the Sun.

Experiment 3 went into the Atlantic Ocean with *Mariner 1*. But Experiment 4 finally made it into interplanetary space with *Mariner 2*. Our jubilation ended, however, when we saw our first data. The spectra formed by sequential readings of each of our 11 energy channels didn't look anything like the simple spectral peak, corresponding to 300 kilometer-per-second protons, that we were expecting. Our spectra had a number of peaks and valleys. After a few nervous weeks we realized that some of the valleys were caused by electronic transients shifting the zero level of the low-ion-flux channels and that the solar wind really had two spectral peaks – one caused by protons (hydrogen ions) and the other by alpha particles (helium ions). We had measured not only the speed, but also the chemical composition of the solar wind.

The *Mariner 2* solar wind experiment proved that Parker's theory was basically correct. We were able to show that the solar wind blew continuously with densities and speeds roughly in agreement with his calculations. The wind was found to be organized into high- and low-speed streams, each persisting for several days. Furthermore, the chemical composition varied with time, and the protons and alpha particles had distinctly different temperatures. Modern solar wind research is still concerned with explaining the causes of some of these features of the solar wind discovered by *Mariner 2*.

Marcia Neugebauer has served as Manager of JPL's Space Physics Section and is currently in charge of the Mariner Mark II *Development Flight Project.*

VENUS ON DISPLAY



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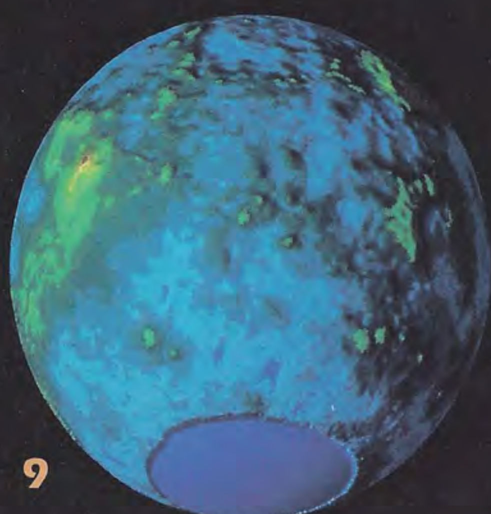
Mercury, Venus, Mars, Jupiter and Saturn have all become familiar faces through pictures taken by Earth-based telescopes and images returned by visiting spacecraft. But there are different, non-photographic ways of "seeing" a planet. The cloud-shrouded surfaces are hidden from orbital cameras such as those on the Pioneers and Voyagers. The Soviet Venera craft have returned pictures of the Venus surface immediately around the landed spacecraft. But the Pioneer Venus Orbiter, which encountered the planet on December 4, 1978 and continues to operate, was the first spacecraft to give us a global view of Venus. The radar instrument carried by the Orbiter is capable of "seeing" through the thick sulfuric acid clouds, and from the data returned by the spacecraft, scientists and technicians have been able to create a motion picture of the rotating surface of Venus.

The radar data from the Pioneer Venus Orbiter were collected by the Deep Space Network and successively processed through computers at the Ames Research Center, the Massachusetts Institute of Technology, the United States Geological Survey and the Computer Graphics Laboratory at the Jet Propulsion Laboratory, where Dr. James Blinn produced the images shown here and on our cover. This series of images portrays Venus as it might be seen by an observer with radar eyes in orbit above the planet. The colors are not the true colors of Venus, but indicate surface elevation as measured by the Pioneer radar altimeter. The lowest elevations are dark blue and the highest points are red. The data cover all of the planet except for small regions near each pole.



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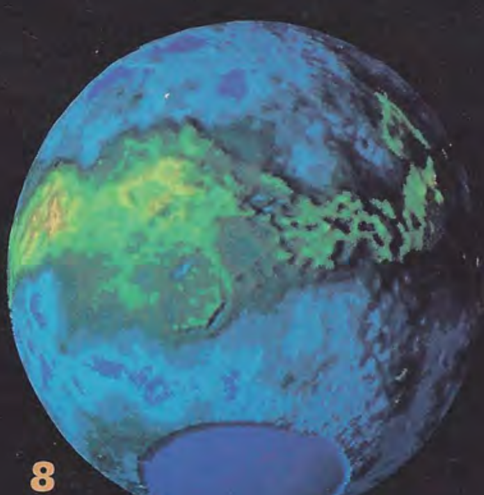
The topography of Venus is clearly different from that of Earth, but the
of the differences is as yet unknown. Elevations on Earth divide into two
groupings (a bimodal distribution) corresponding to the continents and th
floors. The total range in relief, from Mount Everest to the Marianas Trenc
is about 20 kilometers. On Venus, with respect to an arbitrary "sea level"
6051 kilometers, the highest point (on Maxwell Montes) is 11.1 kilometer
and the lowest (in Diana Chasma, at Latitude 14° South, Longitude 156°
depressed by 2.0 kilometers, for a total range in relief of 13.1 kilometers.
statistics of Venus' topography are similar to those of Earth's continents; i
70 percent of the total area lies within one kilometer of the most commo

Some large, nearly circular features on Venus may be
impact basins, and other topographic features suggest t
landforms. A higher-resolution radar survey, like that pl
Radar Mapper, will be needed to confirm or reject these



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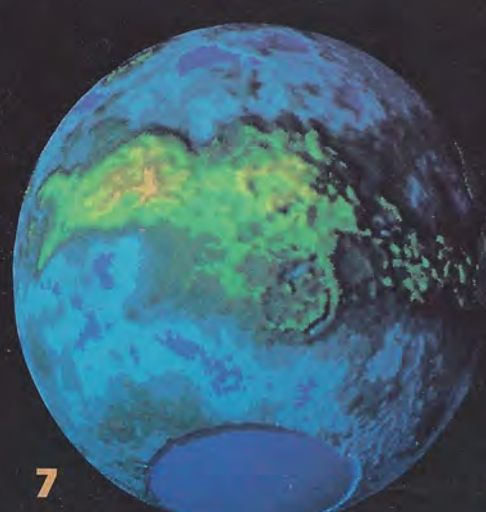

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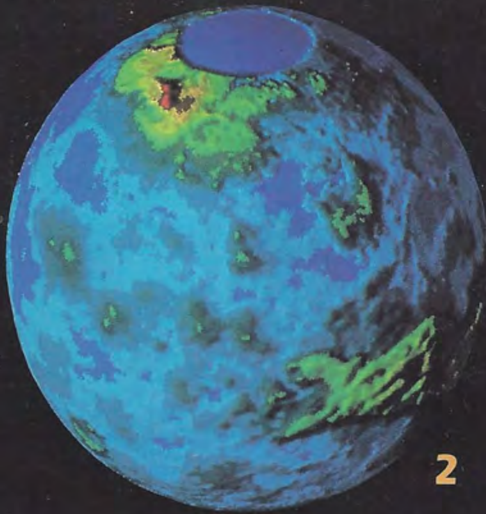

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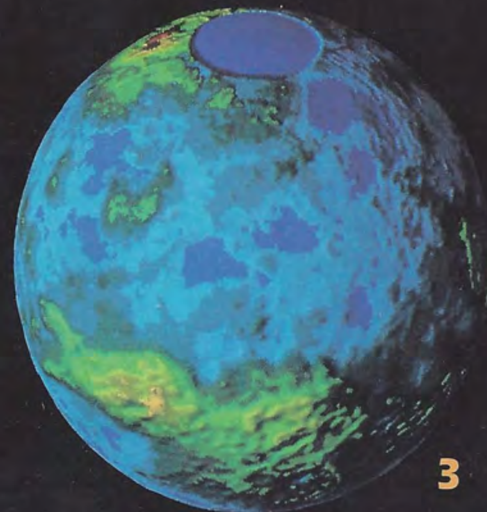

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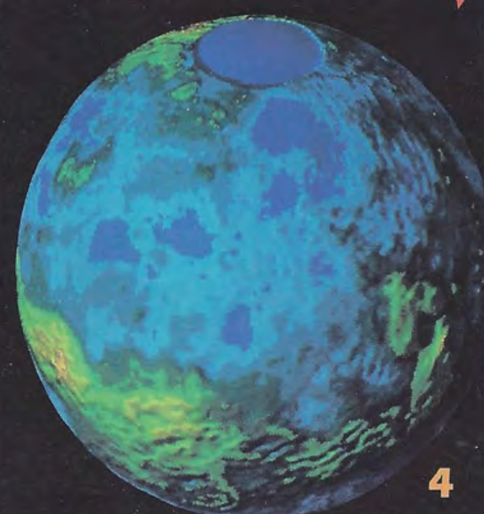
Figure 1: The sequence begins with the great highland Ishtar Terra, with its highest region Maxwell Montes. These mountains rise more than 10 kilometers above the surrounding plains.

Figures 2–5: Proceeding eastward around the planet, we view the vast equatorial highland Aphrodite Terra which stretches thousands of kilometers around Venus.

Figures 6–9: The scan of the planet from the southern hemisphere begins. We can now see the small highland called Alpha Regio, so named as the first major feature to be detected by ground-based radar. Alpha Regio is the "Greenwich Meridian" of Venus, having been chosen (arbitrarily) as the locale through which the 0° longitude meridian passes.



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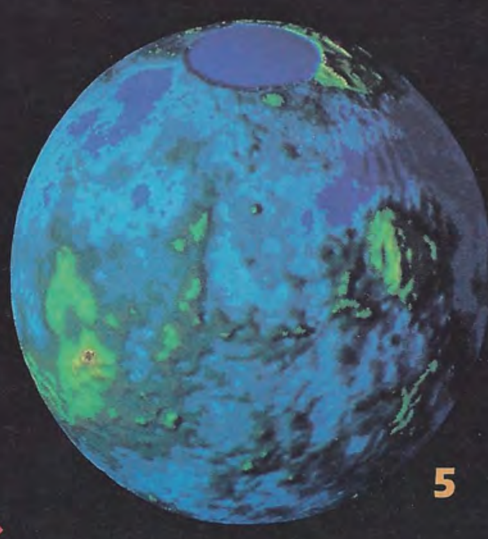

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COMPUTER GRAPHICS: JAMES BLINN AND WALTER BROWN, JPL; PETER FORD, MIT; AND ERIC ELIASON, USGS.

Highlights of the *Venera* Missions to Venus

by M. Ya. Marov

Among the nine major planets of the solar system and their many satellites, Venus is distinguished mainly by the uniqueness of its atmosphere. For a celestial body possessing a solid surface this atmosphere is unusual both in its mass and in the quantity of accumulated heat that it retains. It seems to me that this alone guarantees a permanent interest by planetary astronomers in the study of our neighboring planet.

It is no exaggeration to say that the basic features of Venus have been established with any degree of confidence only in the last two decades, thanks mainly to information from spacecraft missions. The age of Venus exploration was opened by the *Mariner 2* fly-by in December, 1962 that allowed rather accurate radiometric measurements. The next fly-bys, although they transmitted no scientific information, were *Venera 2* in February, 1966 and *Venera 3*, which, in the same month, impacted the planet.

The first *in situ* measurements in the atmosphere of another planet were made by the *Venera 4* spacecraft in October, 1967; it returned back to Earth important data on the principal chemical constituents and other atmospheric parameters beneath the visible clouds. It probed the Venus atmosphere on the night side down to a level with a temperature of 260° C and a pressure of 18 bars (surface pressure on the Earth is, by definition, 1 bar). The craft was crushed at this level, 22 kilometers above the surface, but this fact was not at once evident. At that time no one knew how far beneath the cloud deck the surface was. Estimates of surface pressure varied by more than two orders of magnitude, from a few bars to many hundreds of bars. The situation was complicated by the ambiguous reading of the *Venera 4* radio altimeter. (It was later clarified by the combined analysis of *Venera 4* and *Mariner 5* fly-by data and groundbased radio astronomy and radar measurements.) There was a heated discussion on the matter during the 1968 COSPAR (Committee on Space Research of the International Council of Scientific Unions) meeting in Tokyo, between Carl Sagan (who argued that *Venera 4* had ceased transmitting more than 20 kilometers above the surface) and the author (who argued that *Venera 4* had reached the surface). A. D. Kuzmin tried to find a compromise by assuming a 20 kilometer mountain where *Venera 4* had landed. (Unfortunately such a mountain has not been revealed by the *Pioneer* Venus radar mapping!)

The *Venera 4* mission was the beginning of an elaborate program of Venus research. It was followed in due course by *Venera 5* and *6* in May, 1969, penetrating the nocturnal atmosphere to the 17 kilometer altitude level. *Venera 7*, in December, 1970 was the first spacecraft to reach successfully the surface of Venus. *Venera 7* confirmed the earlier adiabatic extrapolation of atmospheric parameters by V. S. Avduevsky, M. Ya. Marov and their co-workers that predicted values of 460° C for surface temperature and 90 bars for surface pressure (at the level corresponding to a mean Venus radius of 6052 kilometers). An adiabatic (convective) temperature structure for the atmosphere beneath the clouds was deduced from a thermodynamic analysis. These results were confirmed again from the more detailed measurements made by the *Venera 8* spacecraft, which landed on the illuminated hemisphere of Venus near the morning terminator in July, 1972.

The *Venera 4–8* spacecraft comprised the first generation of Soviet Venus vehicles and were similar in design. Each had a mass of 1100–1180 kilograms and consisted of a flyby bus and a descent module (lander) of mass 380–475 kilograms. The lander would separate from the bus at a distance of 20,000–40,000 kilometers from Venus and enter the atmosphere of the planet at a velocity of 11.2 kilometers per second at an inclination of 50–70° to the local horizon. A drogue parachute was deployed when, due to aerodynamic drag, the entry velocity decreased to 210 meters per second, and the main parachute deployed when the atmospheric pressure reached about 0.5 bars. The heat-resistant parachute could withstand an ambient temperature as high as 525° C.

The development of the *Venera* spacecraft required that many complex technological problems be studied and solved. Much attention was paid to designing and testing effective thermal insulations, and to additional measures to prevent the rapid heating of the lander interior. Porous and honeycomb-type materials were utilized; they also possessed high structural strength. The thermal accumulators, based on lithium crystal hydrate phase transfer at a temperature of about 30° C, served to retard heat transfer from the outside; they also froze the lander to about −10° C (through a bus thermocontrol system) before entry into the Venus atmosphere. Special ground-based facilities were also developed to simulate descent through the Venus atmosphere and operation on the surface. I remember one technician asking me whether we could reproduce the Venus atmospheric conditions reliably in the simulator. After my affirmative reply he asked: "Then why do you have to go to Venus, if you already know so much?"

Measurements of chemical composition made on *Venera 4*, *5* and *6* by A. P. Vinogradov and his co-workers with gas-analyzers showed that the Venus atmosphere contains 94 ± 3 percent by volume of carbon dioxide, and that the abundance of nitrogen is less than 3.5 percent. These findings are entirely confirmed by the recent *Venera 11–14* and the *Pioneer* Venus mass-spectrometry and gas-chromatography experiments. The abundance of oxygen was overestimated by the early *Veneras*. Data on water vapor abundance were mutually inconsistent until recently: An abundance of about 0.2–0.5 percent derived from earlier *Venera* readings near the bottom of the clouds was confirmed by *Pioneer* Venus gas chromatography, and by new measurements by Yu. I. Surkov and co-workers with the humidity sensor onboard *Venera 13* and *14*. However, the *Venera* spectrophotometry data by V. I. Moroz and co-workers argue for 1–2 orders of magnitude less water, especially in the atmosphere below 20 kilometers. A variable humidity profile was most recently found by the author and his co-workers from calculations of the heat balance in the Venus troposphere, using rather accurate data for CO_2 opacity. Within a layer 20–25 kilometers above the surface, carbon dioxide alone can absorb all the outgoing infrared radiation; only at higher altitudes is some H_2O needed, with a maximum value as low as 0.01 percent at

40 kilometers. Thus, the spectrophotometric data on water abundance seem to be more reliable.

The *Venera 4–8* missions made the initial reconnaissance of the planet Venus. Besides the atmospheric structure and the principal atmospheric constituents, these early *Veneras* reliably measured the attenuation of sunlight by the atmosphere and cloud. The illumination at the surface was first measured by V. S. Avduevsky and the author, with their co-workers, on *Venera 8*. The measurements showed that 2–3 percent of the sunlight that reaches the cloud tops penetrates to the surface of the planet, and thus confirmed the hypothesis first put forward by Carl Sagan that a runaway CO_2/H_2O greenhouse is the principal mechanism responsible for the "hellish" climatic conditions on Venus. The variable attenuation of sunlight also argued that the main cloud deck lies at an altitude above 49 kilometers and that there is a rather rarefied cloud (later called a subcloud haze) between 49 and 32 kilometers.

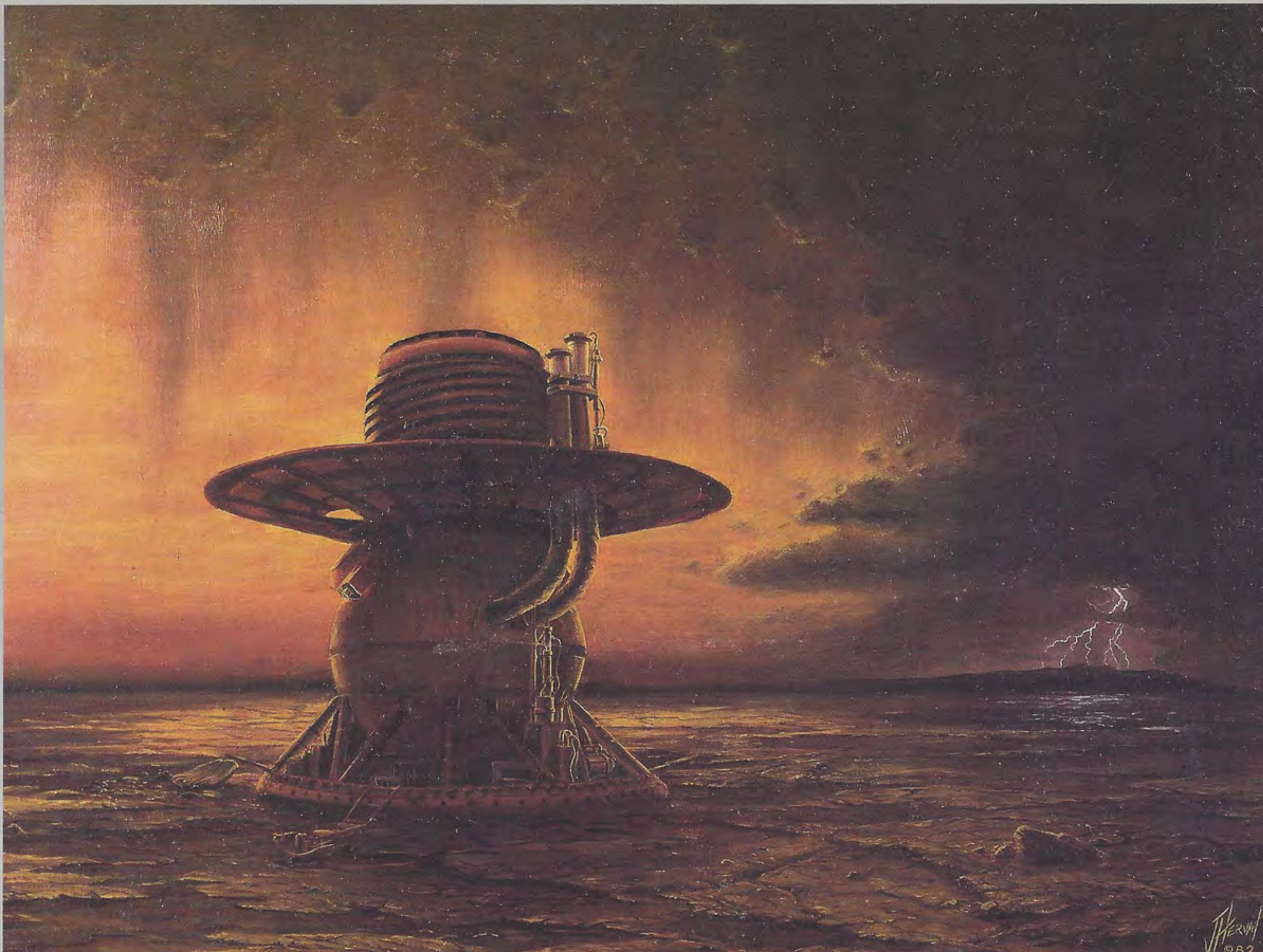
Together with radiative transfer, atmospheric motion is undoubtedly important in the thermal regime of Venus because it is responsible for the fact that the temperatures are almost equal at the equator and at the poles, although much more sunlight arrives at the equator. Data on the horizontal wind velocities in the Venus atmosphere beneath the clouds are also important for understanding the four-day super-rotation at the visible cloud deck level. Information on these winds was obtained from the Doppler effect on the radio transmissions from *Venera* landers during their descents, beginning with *Venera 4*. The measurements made by V. V. Kerzhanovich, the author and their co-workers showed a persistent pattern of zonal wind systems with a velocity increase from 0.5–1 meters per second at the surface to about 100 meters per second at a height of about 50 kilometers. These early findings were confirmed by subsequent *Veneras* and later on by the *Pioneer* Venus probes using the technique called Very-Long-Baseline Interferometry. In addition, very low (less than 1 meter per second) wind velocities were obtained by *in situ* measurements with the anemometers on *Venera 9* and *10* spacecraft by V. S. Avduevsky, the author and their co-workers.

Beginning with the *Venera 8* mission, studies were initiated on the surface properties of Venus. The first measurements were performed by A. P. Vinogradov and co-workers with a gamma ray spectrometer to determine the abundance of radioactive uranium, thorium and potassium in the rocks. The technique was quite similar to that first employed by the same scientific team to study the composition of the Moon from the *Luna 10* orbiter. Later experiments with gamma ray spectrometers were carried out on the *Venera 9* and *10* landers, followed most recently by the first measurements of the elemental composition of the rocks of Venus, performed by V. L. Barsukov, Yu. A. Surkov and co-workers with the *Venera 13* and *14* landers. The bulk

(continued on page 17)

***BELOW:* Horizon to horizon panoramas from the *Venera* spacecraft. The top photograph was returned by *Venera 9*; the flying pangolin is supposedly visible in the lower right. The *Venera 13* (middle) and *14* (bottom) images have been computer-enhanced and show opposite sides of the spacecraft from those photos previously published in this magazine.**

We would like to thank L. B. Ronca of Wayne State University for his help in obtaining these Venera 13 and 14 images.



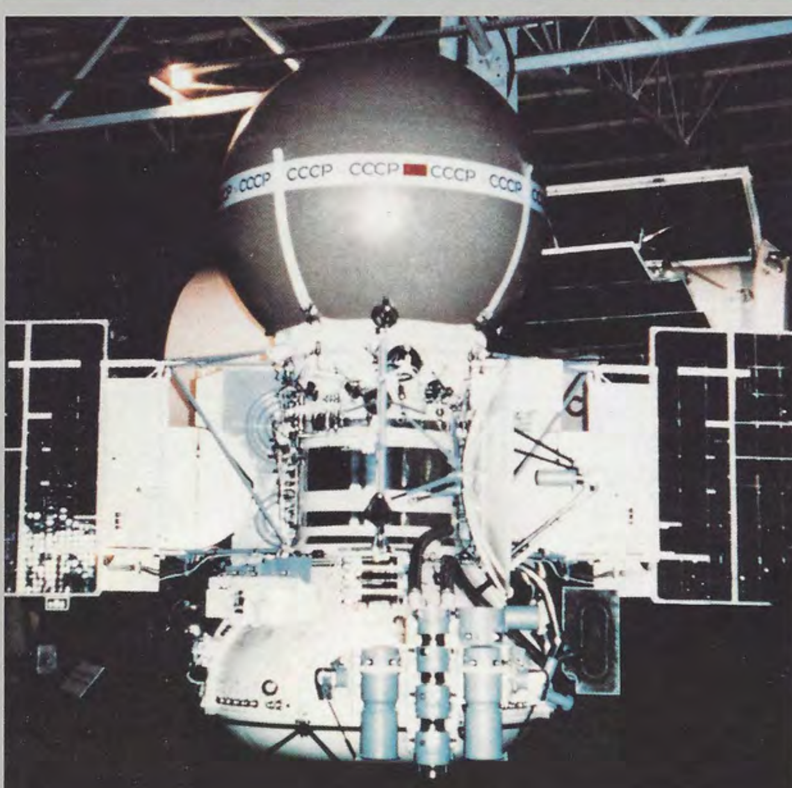


PHOTO: JPL/NASA

TOP:
***Venera 14** sits on the scorching Venus surface.*

ABOVE:
A possible explanation for the inhospitable conditions on Venus.

LEFT:
A display model of the Venera 9 and 10 spacecraft. The sphere at the top houses the lander.

(continued from page 15)
of the data point to the Venus surface being mainly composed of tholeitic basalts, which are similar to common rocks in the Earth's oceanic crust. In some, more restricted areas, the rare alkaline basalts (typical mainly of continental rift zones in the Mediterranean) occur. Basaltic rocks were also indicated by measurements of soil density onboard *Venera 10* by Yu. A. Surkov and co-workers. The value obtained, 2.7 grams per cubic centimeter, happens to be in good agreement with an estimate deduced much earlier from ground-based radar data.

The *Venera 9* and *10* flights were followed by the *Venera 11, 12, 13* and *14* missions, and the next phase in the exploration of Venus had begun. These *Veneras* belong to a new generation of spacecraft with greater capabilities. The mass of the lander has been increased to more than 1500 kilograms, and the landing strategy has been changed to accommodate two conflicting requirements: a slow descent through the clouds, and a fast penetration of the thick atmosphere below, to prevent an enormous heat buildup before landing (and thus to increase the time of operation on the surface). To accomplish this strategy, the main parachute (180 square meters in area) after deployment at 62 kilometers is released below 50 kilometers; thereafter, an aerodynamic drag ring provides stabilization during descent and a touchdown at a velocity of 7 meters per second.

Venera 9 and *10* each consisted of an orbiter and a lander, the latter being separated before entry and relaying information through the orbiter back to Earth during descent and after landing on Venus. In October, 1975, the first artificial satellites of Venus were injected into orbit, and two landers were operating on the surface for more than an hour. *Veneras 11* and *12*, which landed in December, 1978, and *Veneras 13* and *14* which landed in March, 1982, relayed their telemetry through flyby modules.

These missions contributed much to our knowledge about Venus. Both atmospheric and surface properties were carefully studied. Atmospheric chemical composition was emphasized, and studies were performed on minor constituents and the isotopic ratios of noble gases. Investigations begun with *Venera 4*, on the magnetic field of Venus (which, it turns out, does not exist), on the structure of the upper atmosphere and ionosphere, and on their interaction with the solar wind, were continued by S. S. Dolginov, K. I. Gringauz, O. L. Vaisberg, V. G. Kurt, V. A. Krasnopolsky and their co-workers.

The three-layer structure of the main cloud cover of Venus, and the principal microphysical properties of the clouds and the haze aerosols beneath the clouds, were discovered through nephelometry onboard *Venera 9* and *10* by the author and his co-workers. Some puzzling problems arose from the mass-spectrometry findings by Istomin and co-workers on *Venera 11–14* (and independently by the corresponding *Pioneer* Venus team): an enrichment in the Venus atmosphere, as compared to the Earth's, of the primary isotopes of argon and neon, and probably of krypton and xenon as well. The results are of great importance for understanding the origin of the planets. What differences in initial conditions or early history could account for these differing abundances of chemically inert gases in the atmospheres of adjacent planets? Gas chromatography measurements by L. M. Mukhin and co-workers uncovered the mixing ratios of a number of minor constituents, including sulfur-bearing compounds.

Venera 9 and *10* returned to Earth the first photographs of the surface of Venus, followed by new sets of images, including those in color sent by *Veneras 13* and *14*. The analysis of these panoramas, made mainly by the scientific team led by K. P. Florensky, has opened a new area of research on the surface geology and crustal formation of Venus. Some people have even claimed to find signs of life in the *Venera 9* picture. In the bottom right-hand corner, it is claimed there is a flying pangolin (with a single cyclopean eye inspecting the lander!) I believe it is more likely, however, that this is the sort of igneous rock called a volcanic bomb. After one of my public discourses, I was asked how smart this bomb (with a tail!) might be.

But let us return to more evident aspects of the *Venera* pictures. We believe that there is rather definite evidence in the *Venera 13* and *14* panoramas for a layered, sedimentary structure, probably connected with repeated geological events in the fairly recent history of the planet. Contemporary vulcanism was assumed on Venus, in particular in the terrain adjoining the Beta and Phoebe Regia where *Venera 9, 10, 13* and *14* have landed, in part to explain the intense low-frequency electromagnetic noises first discovered by L. V. Ksanfomality and co-workers with *Venera 11* and *12*, and also detected as radio whistlers by the *Pioneer* Venus Orbiter. The sources of the emission were located near the surface; and they appear to be correlated well with the most elevated regions on the planet, which are probably of volcanic origin.

Two decades ago, soon after the first principal discoveries about Venus had been made, we asked the question: Why is Venus so different from the Earth? Unfortunately, despite enormous progress in the intervening years, we are scarcely able to answer the question unambiguously and in detail today. Have we taken into account every relevant factor in attempting to find an explanation? Probably not. In this regard let me refer to the adjacent cartoon from the *Astrocosmos* newspaper, issued during the August, 1982 General Assembly of the International Astronomical Union in Patras, Greece. If the inhabitants of Venus could to this extent lead us into error about their planet, they must be much more intelligent than we.

In this article there was room to mention only a few of the *Venera* science teams, mostly those with whom the author had the pleasure of working for many years. I thank all those who made the *Venera* missions possible. More detailed results of these and other missions are summarized in the following:

- ☐ M. Ya. Marov, 1972. Venus: A Perspective at the Beginning of Planetary Exploration. *Icarus 16*: 415–461.
- ☐ A. D. Kuzmin, M. Ya. Marov, 1974. Physics of the Planet Venus. Nauka, Moscow. (NASA Technical Translation TT F-16, 226, 1975.)
- ☐ M. V. Keldysh, 1977. Venus Exploration with the *Venera 9* and *10* Spacecraft. *Icarus 30*: 605–625.
- ☐ *Soviet Space Research*, Special issues for *Venera 9, 10, 14* (5, 6), 1976.
- ☐ M. Ya. Marov, 1978. Results of Venus Missions. *Ann. Rev. Astron. Astrophys. 16*: 141–169.
- ☐ *Soviet Space Research*, Special issue for *Venera 11, 12; 17* (5) 1979.
- ☐ *J. Geophys. Res.*, Special issue for *Pioneer*-Venus, *85* (A13) 1980.
- ☐ *Soviet Astronomical Journal, Pis'ma*, special issue for *Venera 13, 14; 8* (7), July 1982.

Mikhail Marov is a Department Chief at the M. V. Keldysh Institute of Applied Mathematics, Soviet Academy of Sciences, Moscow, a Professor of Planetary Physics at Moscow State University, and one of the leading figures in the exploration of Venus with the Venera *series of interplanetary spacecraft.*

Society Notes

by Louis Friedman

When The Planetary Society was founded in 1980, Drs. Sagan and Murray set it three goals: (1) to encourage a realistic continuing program of planetary exploration and the search for extraterrestrial life; (2) to serve as a focus for the many individuals and organizations that share our objectives; and (3) to involve the public in the adventure of planetary exploration by helping to initiate new endeavors. They thought that the third goal was several years in the future, after the Society had reached some stability and perhaps had some reserve funds for actual scientific and engineering support. However, the Society's phenomenal growth and the contributions from our members have allowed us to fund research and development projects much earlier than expected.

Our first grant, made before we even had 500 members, was made to the *Viking* Fund. At that time they were engaged in a credible attempt to raise private money to show public interest in keeping the *Viking* data coming from Mars. A little later, we were able to provide two critical grants to an optical telescope project at the University of Pittsburgh's Allegheny Observatory for a new effort to find extrasolar planets – planets around other stars. The discovery of such planets would be an important contribution both to theories of solar system evolution and to the search for extraterrestrial life.

Our biggest project to date is the funding of "Suitcase SETI," Dr. Paul Horowitz' multi-channel signal analyzer which looks at special frequencies in the radio spectrum. After successfully testing the instrument at the Arecibo radio telescope, Dr Horowitz took it back to Harvard University. He has suggested that it be dedicated to a comprehensive survey at "magic" frequencies on an otherwise unused Harvard radio telescope. The Planetary Society is considering further support of Prof. Horowitz' important work.

We are also excited by Eleanor Helin's discovery of the Earth-crossing asteroid 1982DB, as reported in our July/August 1982 issue. In her article, Ms. Helin described the scientific and more general importance of near-Earth asteroids. Dr. Sagan has suggested a human mission to a carbonaceous near-Earth asteroid to bring back samples for analysis. To date, telescope observing time for examining these small, very faint objects has been lacking. The World Space Foundation, an organization best known in connection with the solar sail (see our June/July 1981 issue), has undertaken an asteroid project in support of Helin's work at the Mount Palomar Observatory. The Planetary Society is pleased to announce a grant of $5500 to the World Space Foundation to be used under Eleanor Helin's direction for observations and, possibly, the discovery and identification of new near-Earth asteroids.

Our "Mars Institute" is also progressing. We have now formed an advisory committee of several leading Mars scientists, polled the scientific community about potential courses and topics for research, and begun planning a two-pronged approach that would enable undergraduates, and perhaps high school students, to work on Mars exploration problems, and would stimulate additional research on the colonization of Mars.

We are pleased with our "seed" efforts in asteroid research and the Mars Institute. But it is with SETI that we have had our greatest reward. The amount we can contribute for a small private effort like Suitcase SETI is miniscule compared to the needs of a moderately-sized program by NASA. However, NASA's program had been cut off by Congress in Fiscal Year 1982. As we report in "Washington Watch," the Society played a major role in convincing Congress and NASA to reinstate the SETI program in Fiscal Year 1983. It now appears that there will be a SETI program and that it will continue for at least several years. Thus, the value of "seed" money is proven. We have been able to use small amounts of research and development money to bring together the ingredients necessary to continue government exploration of the solar system and the search for extraterrestrial intelligence.

We are honored that Academician Roald Sagdeev has joined us as an Advisor (see box). This is an important step in making the Society truly a planetary endeavor. We are now pursuing contacts in the Soviet Union, England, France, the Netherlands, Japan, China, Canada and Australia, and we are expanding membership activities in all of these countries. Recently, *The Planetary Report* was sent to some 20,000 subscribers to a Dutch television course on space science. Many joined The Planetary Society, providing our first "mass membership" incursion into another country. We have also begun a direct mail membership campaign in Canada.

As we close 1982, we can reflect on a very important and busy year for Planetary Society members and for the development of our organization. We continue to reach more and more people, permitting them to share in the results of planetary exploration. Our products and services to members have doubled, and we look forward to continued expansion. We anticipate more projects, new products and services (including a new map of Mars). Most important, we hope to see the start of a new planetary mission to orbit Venus, peer through its clouds, and see what may be one of the most exciting and dynamic surfaces in the solar system. This, of course, is the Venus Radar Mapper mission. Members are encouraged to continue to promote this mission, and future planetary exploration, by writing to the President, the President's Science Advisor, their Congressmen, newspapers and magazines about this subject and The Planetary Society. □

Our New Advisor

Roald Z. Sagdeev has joined The Planetary Society's Board of Advisors. Academician Sagdeev is the Director of the Institute for Space Research (IKI) of the Soviet Academy of Sciences and a renowned leader of the Soviet space science and exploration program. His research interests have ranged over a wide variety of topics in the field of plasma physics, with applications both in fusion power research and in the exploration of planetary magnetospheres. As Director of IKI, he has participated in a number of international space research investigations, becoming known to colleagues in several countries for his outgoing manner and ready wit as well as for his expertise. Dr. Sagdeev's latest international initiative has been to promote a group of cooperative international scientific investigations for the VEGA (Venera-Halley) missions to be launched by the USSR in December, 1984, fly by Venus in June, 1985, and intercept Halley's Comet in March, 1986. (Another member of our Board of Advisors, Professor Jacques Blamont, Chief Scientist of the French National Space Agency, CNES, also participates in that venture.) We are delighted that Dr. Sagdeev will be among those distinguished leaders in the humanities and the sciences who advise us as we advance toward our goal: to enable people everywhere to share in the adventure of exploring the solar system.

WASHINGTON WATCH

by Louis Friedman

By the time you read this column, the elections in the United States will be over and the shape of the new Congress will have been determined. We will have to wait a few months to see what effect there will be on the course of planetary exploration and space issues. Much will depend on the President's budget for Fiscal Year 1984 which he will present in late January, 1983. We hope that the Venus Radar Mapper mission will be the principal new start for NASA. This could be the first planetary mission proposed for a new start since the *Galileo* project in 1977 (then scheduled for a 1981 launch on the Space Shuttle!).

The Fiscal Year 1983 budget finally seems complete. After a great deal of effort by Planetary Society members and many others in the planetary science community, Congress provided money for the continued tracking of the *Pioneer* and *Voyager* spacecraft, the operation of the infrared telescope in Hawaii and the Lunar Curatorial Facility, and for university research in planetary mission data analysis. One congressional committee staff member told us that letters and telegrams from Planetary Society members to his senator had a decisive effect on the committee vote for the additional money.

The major issue, however, that dominated the space science budget was not science but whether the *Centaur* launch vehicle or the Interim Upper Stage would be used in the Shuttle space transportation system to launch *Galileo* and other future missions. In September, Congress reaffirmed its earlier decision to go with the *Centaur* and override the administration's cancellation of that rocket in favor of the Interim Upper Stage. *Galileo* will now be launched one year later than most recently scheduled (in 1986 on the Shuttle-*Centaur*) but it will reach Jupiter one year earlier because it will use a direct trajectory rather than the Delta Vega trajectory required by the Interim Upper Stage (see *The Planetary Report*, May/June 1982).

Also in the 1983 fiscal year budget, the NASA Search for Extraterrestrial Intelligence program was reinstated at an approximately $2 million-per-year level. This was earnestly sought by The Planetary Society, and Dr. Sagan met with Senator William Proxmire specifically to give him information about the program. Senator Proxmire successfully fought to have all funding for SETI dropped from last year's budget, but as a result of his meeting with Dr. Sagan, and other efforts, the senator did not oppose the reinstatement of SETI this year.

We conclude the 1982 series of Washington Watch columns with reference to our commemoration of twenty years of interplanetary flight. We hope that the people who attend this event in Washington, D.C. will focus on the future of planetary exploration. We first passed by Venus in December, 1962, but we have seen its surface details only at a few small spots where the U.S.S.R. has landed spacecraft with cameras. The global mapping mission, the Venus Radar Mapper, that is proposed in next year's budget offers the opportunity to study that surface in detail. It and other possibilities for future exploration of Mars, the asteroids and Titan will be presented and pursued vigorously by The Planetary Society in the coming year.

Louis Friedman, Executive Director of The Planetary Society, spent one year as a Congressional Fellow with the Senate Committee on Commerce, Science and Transportation.

The Case of the Disappearing Asteroid

Some readers of the July/August 1982 issue of *The Planetary Report* may have been a bit puzzled by the discovery photograph of Apollo asteroid 1982DB that appeared on page 5. The asteroid trail was missing. How could even a sharp-eyed scientist find an asteroid in what appeared to be complete blackness? Was this photograph representative of the type of data used in planetary science? Or was there a mistake in the printing?

There was a mistake in the printing. While the magazine was on press, the black ink "flooded," obliterating the asteroid trail in some copies. We are reprinting the photograph here. The inclined trail of the asteroid is labeled B and should be visible in the upper right section of the picture.

As readers of the article, "Discovering an Asteroid," will recall, Eleanor Helin found the asteroid 1982DB while photographing the split comet DuToit-Hartley, which was called simply Comet Du Toit in the article. She has written to us to correct this oversight, and a portion of her letter follows:

"The complete name of the comet (the main component of which appears in the DB discovery photo [A]) is Comet Du Toit-*Hartley*. In my rush to write an account of the discovery of 1982DB, I abbreviated 'Du Toit' and simply didn't add 'Hartley.' Somehow, I didn't catch this oversight when reviewing the draft of the article. In fact, it had been my plan to allude to Malcolm Hartley's accidental rediscovery of Comet Du Toit. Hartley is a staff astronomer at the 1.2 meter United Kingdom Schmidt Telescope Unit in Australia and is a friend of mine. In early February, 1982, on a photographic plate taken for other reasons, he found what appeared to be two comets about a degree apart. He reported the discovery of the two comets and they were given his name. Only after Drs. Brian Marsden and Z. Sekanina had conferred on the nature and orbits of these unusual comets was it recognized that these two comets were actually the Du Toit comet which had split (it is conjectured) in 1975. So, at this time, Comets Hartley 1982a and 1982b became Comet Du Toit-Hartley with split components b and c. The story does get a bit complicated, doesn't it?

"If it hadn't been for Hartley's rediscovery of the Du Toit comet, now split into components, I would not have been trying to obtain a much-needed additional observation on the night of 27/28 February...and Apollo asteroid 1982DB would not have been detected, three hours from opposition in a part of the sky rarely photographed for asteroids. But, because of the course of events, it all came together: a unique photograph was made of the split comet, an Apollo asteroid was discovered in a close encounter with Earth, and we found the best asteroid mission target to date. Serendipity still plays an active role in discovery."

VENUS IN 2002

by James D. Burke

Twenty years ago, on the eve of Mariner 2's encounter, humans knew that Venus was about the same size as Earth, had a dense cloudy atmosphere, and was probably hot (see pages 8–10). Now we know a lot more about the planet and its atmosphere, clouds and ionosphere, but we are still only beginning to explore a whole new world. The Pioneer Venus Orbiter (see page 10) has given us tantalizing glimpses of the planet's surroundings and its general topography (see our February/March 1981 Report), and the Venera Landers and Pioneer Probes (see our May/June 1982 issue) have given us tantalizing glimpses of tiny bits of the atmosphere and surface. In 1985 the Soviet Vega missions will, if all goes well, drop off two more landers (to sample the atmosphere and land on the night side of Venus) as they pass by en route to Halley's Comet, and in coming years orbiting radar missions will vastly improve our maps of Venus' vast, low, rolling plains and its few high, rough continents (see "Washington Watch," page 19, for a discussion of current progress on the Venus Radar Mapper mission). By 1990 we may expect to have knowledge comparable to what we now have for Mars.

What then? Well, we will probably still be wondering how Venus arrived in its present, to us hellish, state. At the surface the temperature is 470° Centigrade, or nearly 880° Fahrenheit, and it does not cool off during the two-month-long night. Fifty to sixty kilometers up in the carbon dioxide atmosphere there is a hazy layer of sulfuric acid clouds. Was Venus once more temperate? Did it ever have an ocean whose water has now disappeared into space? Could it ever have supported life? These questions will probably remain unanswered at the end of the present century. But, being human, we shall still be trying to learn.

Two of the possible techniques for learning more about Venus are already being worked on. One way is to send balloons, and then perhaps a cross between a dirigible and a submarine, into the dense atmosphere for long-term observations over wide regions, at levels where the temperature and pressure are tolerable. Another approach is to develop equipment that can survive indefinitely on the surface, enabling seismic and other long-term measurements similar to those made by the Viking Landers on Mars. The Viking Landers themselves represent a step toward high-temperature equipment; they survived biological sterilization at 125° Centigrade (257° Fahrenheit), and laboratory experiments in later years have shown that some new kinds of electronic components can survive even Venus' temperatures. Because of the Earth's internal heat there is a market here for such components to be used in deep borehole instrumentation, so the development is likely to continue.

Will humans ever go to Venus and live there? Not on the basis of what we know now. The enormous land area of the planet, more than three times that of Earth, will remain unsettled, virgin territory for as far into the future as we can see. "Terraforming," which would convert the atmosphere from a blanket into a radiator and cool the planet down, is but a dream for now, and after twenty more years of scientific progress it is likely still to be a dream.

But, almost surely, we shall know much more by then about how Venus arrived in its present state and about how to preserve the stability of Earth's atmosphere. Thus, the dream of Venus may help to forestall a nightmare on Earth, and even if that connection proves to be distant, we shall be glad, just for the planet's intrinsic interest, that we are continuing to learn about Venus in 2002. □

An artist's conception....

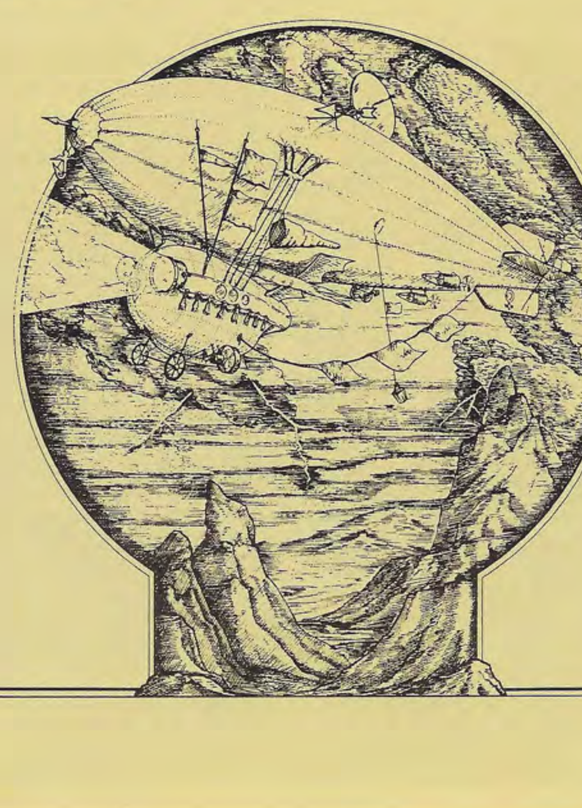


ILLUSTRATION: S. A. SMITH

News & Reviews

by Clark R. Chapman

What does outer space have to offer us? Most readers of *The Planetary Report* probably agree that the exploration of space leads to profound new scientific understanding of the cosmos and also holds the potential for eventual human habitation and exploitation. But hard-nosed critics of the space program want to know what *practical* benefits may be expected. Isn't space mostly a lot of cold emptiness? Yes, but it also contains prodigious quantities of material (although separated by vast distances) and equally immense amounts of energy.

As human beings venture out from the Earth, the first practical benefits are coming from the in-orbit vantage-point above our world. Next will be utilization of energy and material resources that are near the Earth in space. That means solar energy and small, Earth-approaching asteroids. In the September, 1982 issue of *Smithsonian* magazine, William K. Hartmann discusses the promise of harvesting raw materials from the small asteroids. All that is needed, according to Hartmann, is "a little leadership and daring" in order to harvest the $300 billion worth of already-refined metals that he thinks must exist on a small, as-yet-undiscovered asteroid. The appropriate mine-in-the-sky will be found within a decade by the Spacewatch project, if all goes well.

Toward the end of his article, Hartmann ventures some thoughts about the relationship of such space-engineering projects to the environmental movement. Many environmentalists, he notes, distrust large technological projects and oppose large-scale exploitation of resources, whether on Earth or in space. Hartmann feels, however, that by utilizing the vast material resources that exist among the asteroids, we will no longer need to despoil the Earth. Thus, he promises that a "greener Earth" may be the most important practical benefit that can be derived from the next few decades of space exploration.

Hunting for Halley

Lurking in the outer solar system is a tiny, faint, but very famous celestial object. Halley's Comet was last seen in 1911, as it zoomed away from its famous encounter with Earth in 1910. While it won't come so close to the Earth in 1986, interest will be high as spacecraft from Europe, the Soviet Union, and Japan journey to intercept the comet when it is near. Astronomers at big observatories around the world competed to be the first to see the five-mile ball of ice as it slowly approaches (see page 2).

The October issue of *Science 82* has a "slice-of-life" article, by Terry Dunkle, that focuses on a team of Texas astronomers during a few nights last February when they made their bid – unsuccessfully – for the prize. Life at night on a mountaintop in West Texas is beset by clouds, equipment problems, and human foibles. In fact, we read, the real motivations for the search have more to do with winning a race than with science, although science will certainly benefit from the recent recovery of the comet. Dunkle's piece is a rare view of scientists as real people, enjoying their work, and being honest with each other and – through Dunkle – with the world as to what telescopic observing is all about.

Extraterrestrials: Where Are They?

Certainly one of the most profound questions confronting humanity is whether or not we are alone in the universe. We are compelled to answer the question by more than mere curiosity. For example, if we *are* alone, we might learn that the reason is that technological civilizations are prone to self-destruction very soon after they first evolve. The sobering realization of such a fact, if true, could be a powerful inducement for us to survive – to stop the arms race and to protect our life-sustaining environment.

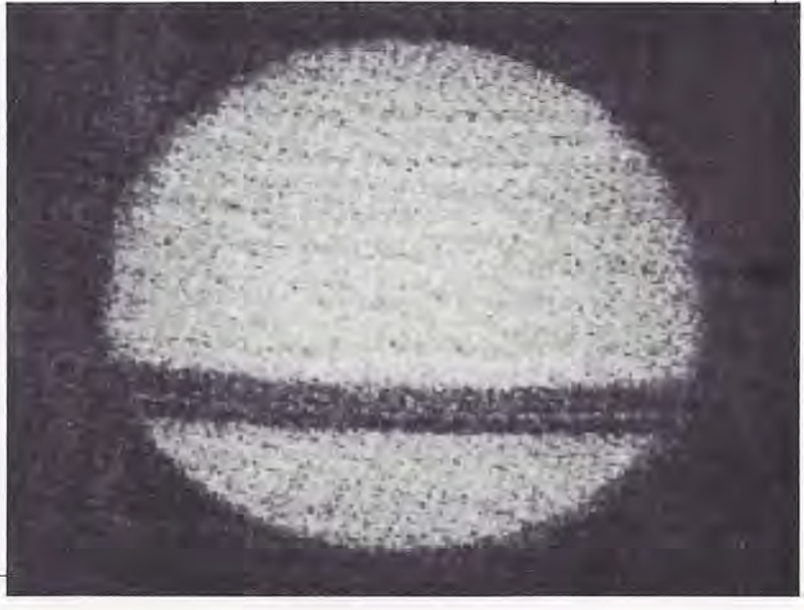
A fine article by Jill Tarter in the October, 1982 *Astronomy* talks about the search for others in space. There has been much philosophizing about the question of extraterrestrial life. Some think it is nearly certain that numerous civilizations exist in the galaxy, while others think it nearly as certain that we are alone. The big question for skeptics is, "Where are they?" Tarter explains that the question has several possible answers. Of course, some folk think that "They" are all around us, in shiny, saucer-shaped spaceships. Others think that we are "Them" or, more exactly, "Their" descendants. Most scientists, however, think that "They" haven't been found, all of which leads Jill Tarter to point out that we really haven't looked very hard.

It's difficult to know how much effort we should put into looking, for a thorough search would be extremely expensive and time-consuming. But if extraterrestrial civilizations are common, then a directed search of some of the more likely nearby abodes (e.g., sun-like stars) could be successful and would be of a very modest cost, especially compared with the significance of the answer. As Tarter writes, now is the right time to do it, before the noisiness of our own civilization forces the extremely sensitive SETI detectors to some protected site like the far side of the Moon, which would be a vastly more costly endeavor.

Rings Resolved by Radio

At a recent meeting in Toulouse, France, experts on planetary rings discussed the *Voyager* data and sharpened their theories about what makes the rings behave as they do. Impressive observations can still be made from the ground, as shown in the picture below of Saturn's radio emission, obtained by Imke de Pater and John Dickel with the Very Large Array of radio telescopes in New Mexico. The fine white line in the rings is the Cassini Division.

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



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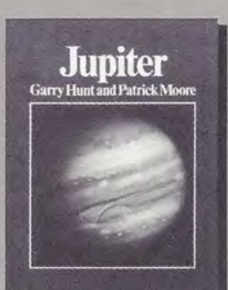
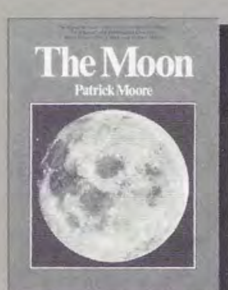
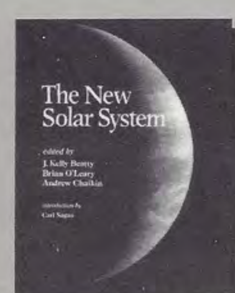


Jupiter—A new look at the largest planet in the solar system, written by Garry Hunt, a member of the Voyager Imaging Team, and Patrick Moore, author and broadcaster. Stunning photographs, maps, diagrams and data fill 96 pages.



The Moon
A brand new atlas of our satellite by Patrick Moore, well-known author and BBC space science broadcaster. This book offers a wealth of pictures, maps and data.

The Voyager Flights to Jupiter and Saturn
The official summary of both Voyagers' encounters with the giant planets. This full color NASA publication highlights the many discoveries about the planets and their moons.



The New Solar System
This marvelous book, edited by J. Kelly Beatty, Brian O'Leary and Andrew Chaikin, brings together the work of 21 renowned planetologists in a dazzling arrangement of pictures and up-to-date information.

THE PLANETARY SOCIETY

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An airbrush artist from Milwaukee, Wisconsin, Mark Paternostro specializes in astronomical art. His work has appeared in Astronomy and Odyssey magazines, the Encyclopaedia Britannica, and in several other publications. Since completing several projects for the Adler Planetarium in Chicago last year, Mr. Paternostro has been working on a book.

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