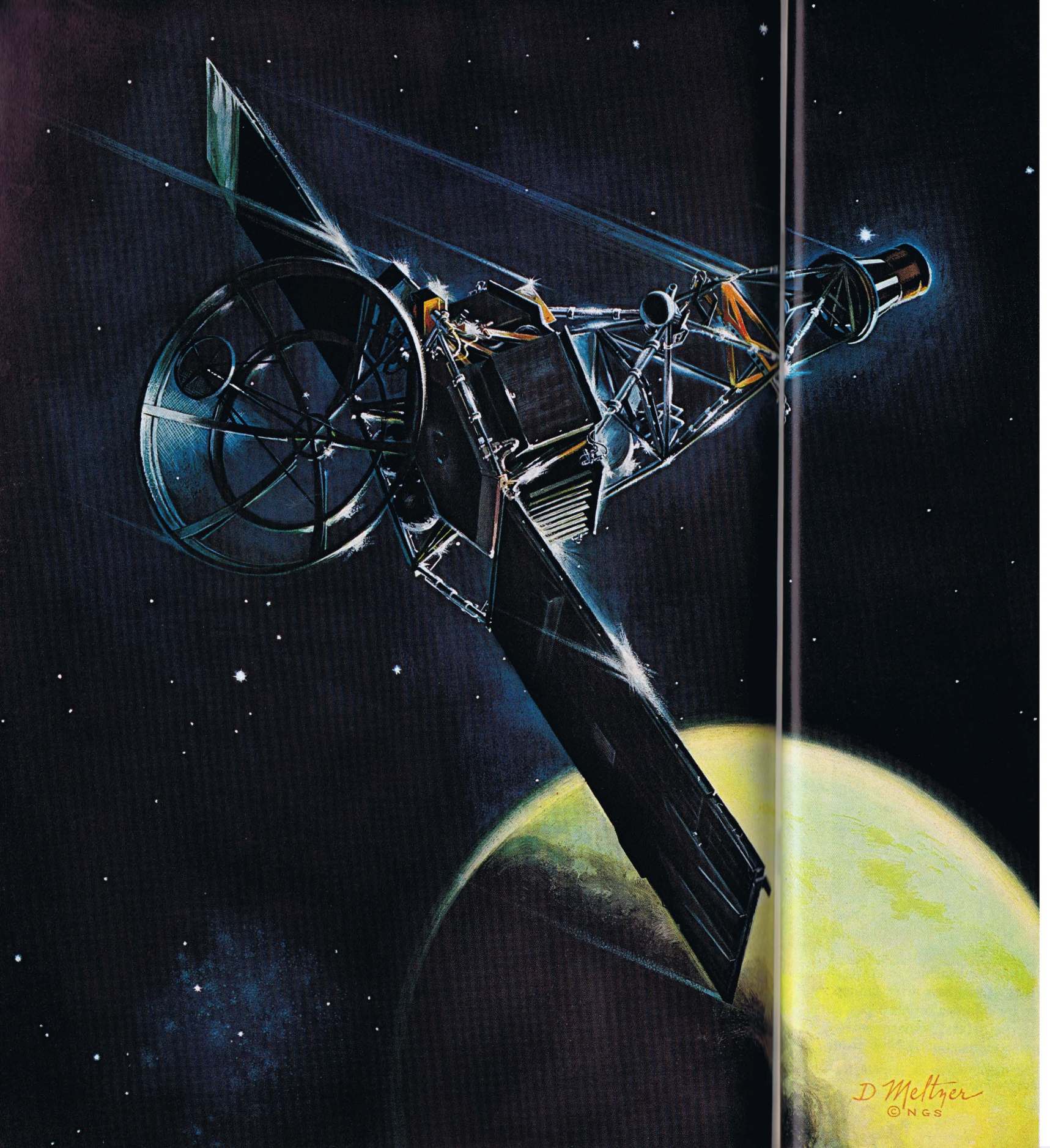

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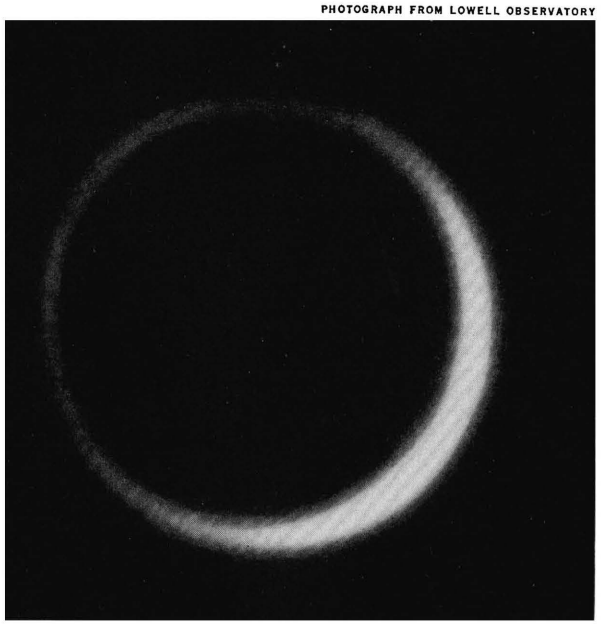


Venus shows a moonlike phase as it swings between sun and earth. Sunlight tints its atmosphere on the dark side.

Dragonfly in space, Mariner II coasts within 21,700 miles of Venus. Winglike solar panels gather energy from the sun. Dish antenna beams the space scout's findings to earth. Artist has added lines of motion to suggest direction of flight.

Mariner Scans a Lifeless Venus

By FRANK SARTWELL
National Geographic Staff
Paintings by DAVIS MELTZER

THE UNGAINLY, skeletal spacecraft sped past the planet, its pulsing instruments seeking data from a surface mantled by bright, lemon-yellow clouds. Man had reached heavenward, and for 35 historic minutes on December 14, 1962, brushed aside the eternal veil of Venus.

For the first time a "live" and functioning scout from earth had visited a neighboring planet. As it hurtled through a great 182-million-mile arc, this emissary, Mariner II, reported back some 9 million bits of data. Its historic report included these findings:

- No life as we know it on Venus.
- Surface temperature averages 800° F., far above the melting point of lead.

• Cloud cover solid, a dense blanket starting 45 miles above the surface, with temperatures ranging from 200° at the base to minus 60° at the top.

• A mysterious cold spot in the clouds over the southern hemisphere, which might indicate a surface feature—perhaps a mountain higher than Everest.

Mariner Weathers Hazards of Deep Space

Its mission over, Mariner sailed on. Now a planet itself, it circles the sun forever. And only now can the magnitude of its accomplishment be judged. The noted British astronomer Sir Bernard Lovell declares it "the most splendid scientific achievement in space."

On its way to triumph, Mariner survived assault by micrometeors. Atomic fragments from the sun, traveling at 500 miles a second, pounded it. Dizziness from a spinning launch threatened its ability to keep its head. That "tired run-down feeling," created by a power failure, afflicted it for a time. Finally, it suffered severe chills and fever, induced by the sun's heat and the deep cold of space.

Nor were these all the problems. There was, to begin with, the difficulty of hitting the target at all—a feat of marksmanship that has been compared to "sitting on a merry-go-round and shooting a bullet to hit a fast-flying sparrow over the horizon."

Incredibly, trajectory engineers determined that Mariner would have to be lobbed into space in the opposite direction from its rendezvous point with Venus. The explanation:

Earth and Venus are locked in solar orbits, with Venus closer to the sun. When an orbiting body slows down, the sun's gravitational pull draws it irresistibly inward. In order to leave earth's orbit and be pulled by the sun toward Venus, Mariner first had to be fired in the "wrong direction." The reason: to lose some of earth's orbital speed—which it had even when it sat "immobile" on its launching pad!

The engineers also had to determine precise speeds and courses for a near-collision of planet and spacecraft on a flight of 109 days.

Among the other perils of Mariner was the fact that the original design had to be discarded when a powerful second-stage rocket, the Centaur, refused to work in time for the flight. Without the strength of the Atlas-Centaur combination, NASA fell back on the Atlas-Agena rocket system that had propelled the Ranger series of moon probes.*

In Pasadena, California, scientists at the Jet Propulsion Laboratory of the California Institute of Technology, makers of Mariner, suddenly had to cut the craft's total weight from 1,150 pounds to 447 pounds. And they had to do it in only ten months—a deadline set by the immutable courses of earth and Venus through the heavens. They took the Ranger and hung on it some of the original Mariner equipment and instruments. The result was the hybrid "Mariner R."

"There's an advantage in having to work so fast," Dan Schneiderman, Spacecraft Systems Manager, told me. "You can't sit around and dream up tricky devices that might fail."

Three Mariners were built, at a cost of $25,000,000. The task required 1,800 man-years of highly skilled labor. Part of this national investment vanished in flames on July 22, 1962, when the first Mariner was launched from Cape Canaveral, Florida. It flew only 290 seconds before it was deliberately destroyed (with its $9 million worth of rockets) because it was off course.

It was later determined that the failure was caused by no more than a misplaced hyphen in the equations fed into a computer!

Spin Imperils Craft in Lift-off

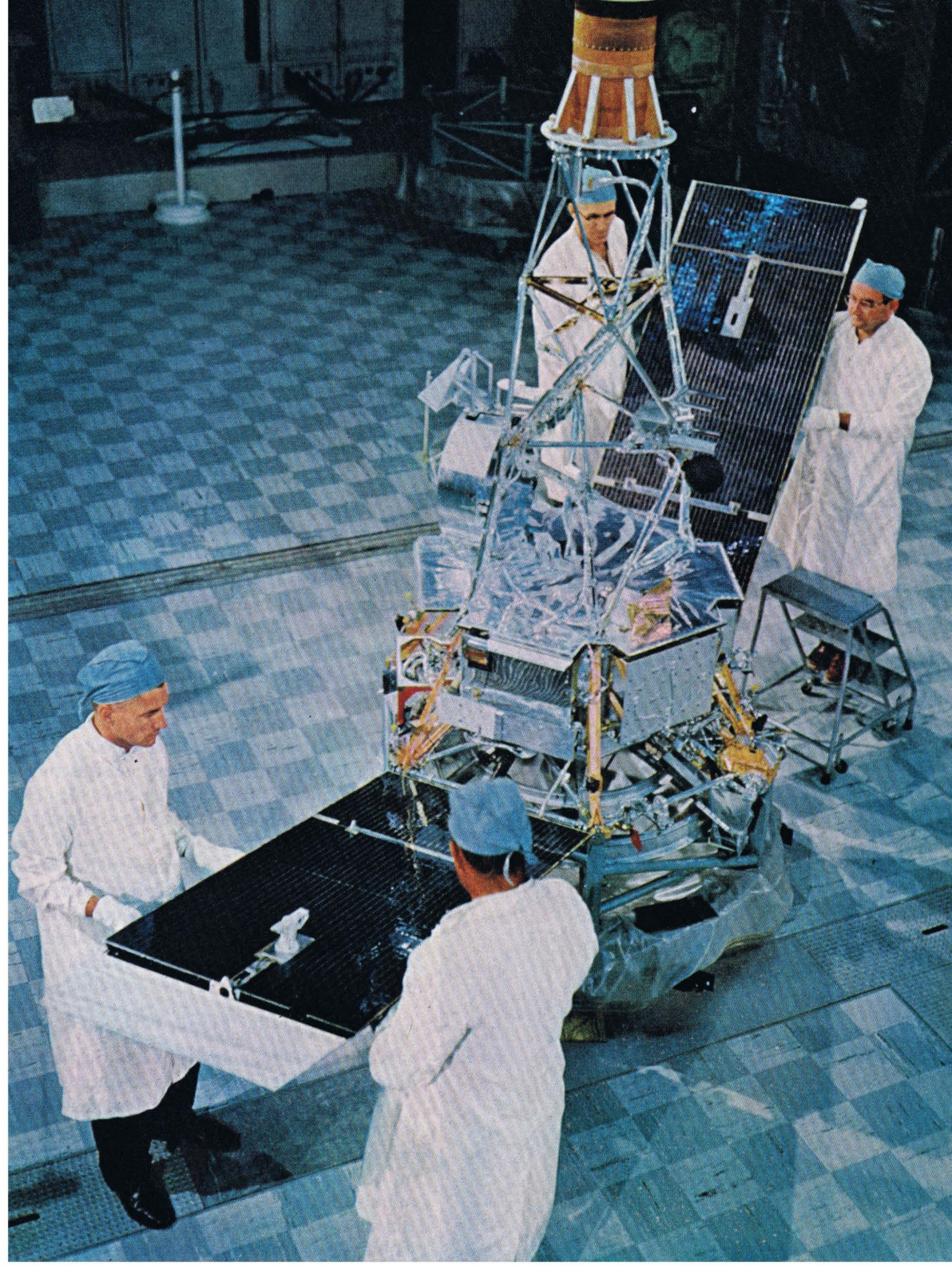
A month later, on August 27, Mariner II was poised on its launch pad.

When the ten-story rocket lifted slowly, then faster and faster, from the Cape, another failure seemed imminent. The rocket began to spin. It rotated on its long axis 35 times during the lift-off—exerting "dizziness" stresses none of the equipment had been designed to absorb. Suddenly, the spin stopped. A launching official leaned back and muttered, "We've had our share of random failures; now we have a random success!"

Only 26 minutes after the flaming Atlas was launched came more good news: The rockets had done their jobs—putting Mariner into the correct orbit and then giving it the final push away from earth (pages 736-9).

An hour after lift-off, the craft "acquired the sun"; that is, it changed its attitude so that its solar panels, spanning 16½ feet, would collect the sun's rays for Mariner to convert into electric energy. Two days after launch, Project Manager Jack James ordered power fed into the "interplanetary" experiments—four of the six instruments aboard. Now, from

*See "Robots to the Moon," by Frank Sartwell, NATIONAL GEOGRAPHIC, October, 1962.



EKTACHROME BY JET PROPULSION LABORATORY

Gleaming Space Bird Flexes Its Wings in a Cape Canaveral Hangar

Surgically garbed engineers test Mariner's solar panels, which fold tightly against the craft's frame during launch. Once in space, the panels extend so their 10,700 cells can catch sunlight and change it to electricity. Shining gold and aluminum reflect sun's heat, protecting instruments. Mariner has now become a man-made planet, in endless orbit around the sun at an average speed of 71,000 miles an hour.

punched tapes or letters on teletype machines, scientists could read the first results of their effort (page 740).

Near the top of Mariner, just under the keglike all-directional antenna, was a cylinder the size of a beer can, housing a device to measure the magnetic fields of space.

On the base of the craft sat a metal plate, five inches by three. Its function was to respond, somewhat like the vibrations of a telephone's mouthpiece, as "cosmic dust," or micrometeors, struck it.

Near the plate was mounted a box from which three tubes projected. Together with a ball-like ion chamber, these Geiger-Müller tubes were to catch, count, and measure fast-moving cosmic rays. A fourth device trapped particles with less energy.

"Find Earth," Sensor Is Ordered

With these four instruments ticking off information, Mariner spun on through space, awaiting one of its most crucial moves—finding and "locking on" to earth.

Up to this time, Mariner had been transmitting data to earth through its omnidirectional antenna, which was relatively weak. But to cross the immense distances that soon would separate it from its home planet—much farther than had ever been spanned by any communication before—a powerful focusing antenna would be used. Hinged from the bottom of the craft, it had to point exactly at earth. Finding earth and locking on was the duty of the earth sensor, a device that worked somewhat like a photographic exposure meter, picking up sunlight reflected from earth.

Since the device had to be sensitive enough to pick up earth even at the end of the voyage —when our planet appears no larger than Venus itself appears from earth—the instrument could not be turned on until seven days after launch. Earlier use could have burned out its mechanism, as the human eye would burn out if it stared at the sun through a lens.

When Mariner gave its sensor the "find earth" command, it was already 1,200,000 miles from its home planet. At the order, trouble immediately developed. The craft's radio signal lost strength instead of gaining.

Technicians in the control room at Pasadena frantically sought to trace the problem. Finally, 36 minutes after the mishap, Mariner II suddenly locked on earth and sent signals of the proper strength.

Later, scientists decided that a freak coincidence had caused the trouble. When the earth sensor was turned on, they believe, it happened to be pointing at earth already. Having seen its target, it automatically began sending signals through the narrowly focused antenna. But that first glimpse of earth was not enough to stop Mariner's rolling motion, and therefore the signal was cast around wildly in space instead of being aimed at earth. It took Mariner 36 minutes to make a complete roll back to its proper position.

All was well now—except that the spacecraft was not on course. Mariner's designers knew from the start that the Atlas-Agena combination was not accurate enough to set the craft on a perfect trajectory, so they built in a corrective rocket motor. After a week of tracking, they could determine Mariner's actual path. Without correction, they concluded, it would miss Venus by 233,000 miles. Mariner's instruments could work only in a narrow target area—between 8,000 and 40,000 miles from the planet. Success depended on a "midcourse maneuver."

Mariner Attempts a Critical Turn

On September 4, Mariner, then 1,490,000 miles out in space, was commanded from the tracking station at Goldstone, California, to release its locks on earth and sun and reorient itself so the rocket in its base would aim in the desired direction. When the craft reported itself ready, the command was given, "Fire!" The rocket burned for 27.8 seconds, delicately boosting Mariner's 60,117-mile-an-hour speed by a mere 45 miles an hour. It was enough.

Almost immediately after the rocket turned off, it was apparent that the maneuver was a success. In its new course, Mariner once more locked on sun and earth. In the Pasadena control room, Jack James, like any proud father, passed out cigars.

Four days later something moving at the speed of a bullet apparently hit the craft. Mariner shuddered, lost lock on the sun, then, three minutes later, regained it. All the symptoms point to an object weighing between a twentieth and fiftieth of a pound striking the spacecraft at 1,600 feet per second. Mariner weathered this blow, and another, 21 days later, without ill effect.

Mariner II's 182-million-mile swing from earth to Venus

VENUS: Position at Mariner II launch

SUN

MERCURY

MERCURY'S ORBIT AROUND SUN

1 **AUGUST 27**: Earth's position on launch date

2 **SEPTEMBER 4**: Traveling slower than earth, Mariner lags behind. Midcourse maneuver corrects trajectory

3 **SEPTEMBER 18**: Mariner, slowed to 6,448 m.p.h. by earth's gravity, now speeds up as sun pulls it toward orbit of Venus

4 **OCTOBER 31**: Accelerating Mariner overtakes earth. Craft has power trouble

Venus passes earth on November 12

Earth on November 12

MOON

5 **NOVEMBER 7**: Electrical system regains power

6 **NOVEMBER 15**: Partial electrical failure reoccurs, but enough power remains for Mariner to do its job

MARS'S ORBIT AROUND SUN

MARS

EARTH'S ORBIT AROUND SUN

PATH OF MARINER

VENUS'S ORBIT AROUND SUN

Earth's position when Mariner passes Venus on December 14

7 **DECEMBER 14**: Mariner II glides past the sunny side of Venus 109 1/2 days and 182 million miles after launch. Findings are radioed 36 million miles to earth

8 **WINGING PAST VENUS**, Mariner continues in solar orbit as a man-made planet

VENUS

Painting by D. Meltzer

Research by Eugene M. Scheel © N.G.S.

JET PROPULSION LABORATORY

AOQ DXQ XZAIZXAZZKZZD X
QKZZD XXDLKADRKHQ ZSQSG
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Cryptogram From Space Tells Venus's Secrets in Coded Letters

Shakespeare's "full star that ushers in the even" hides beneath a blanket of clouds impenetrable to the strongest telescopes.

Mariner (right) scanned sun rays modified and reflected by Venus and sent back a stream of coded information. Men and computers translated these seemingly meaningless letters.

"QSGI" presents a microwave report on water presence and surface temperatures (later found to be 800° F.). "QQKS" gives infrared data on cloud cover (continuous, 15 to 20 miles thick) and cloud temperature (from 200° F. to minus 60° F.). Sensors detected no magnetic field and no Van Allen belt of trapped radiation.

Passing Venus, Mariner communicated with earth to a distance of 53.9 million miles, using only three watts of power. This means that radio contact is probably possible throughout the solar system, a finding vital to manned flight.

All this time, Mariner was telling earth about the unprobed areas it was voyaging. It discovered that throughout these regions the number of cosmic rays—energetic particles believed to originate outside our solar system—is constant. On the other hand, waves of high-energy sun particles, produced by solar flares, came at irregular intervals. Those detected by Mariner, however, were determined to be no hazard to the men who will one day sail the far reaches of this new ocean.

Mariner also confirmed the existence of a constant "solar wind." Made up of electrons and fragments of hydrogen and helium atoms, this energy stream rages from the sun at 200 miles a second when the sun is relatively quiet, with gusts up to 500 miles a second.

No Magnetic "Holes" in Space

Further, Mariner's magnetometer was almost constantly busy, reporting space to be filled everywhere by a faint magnetic field.

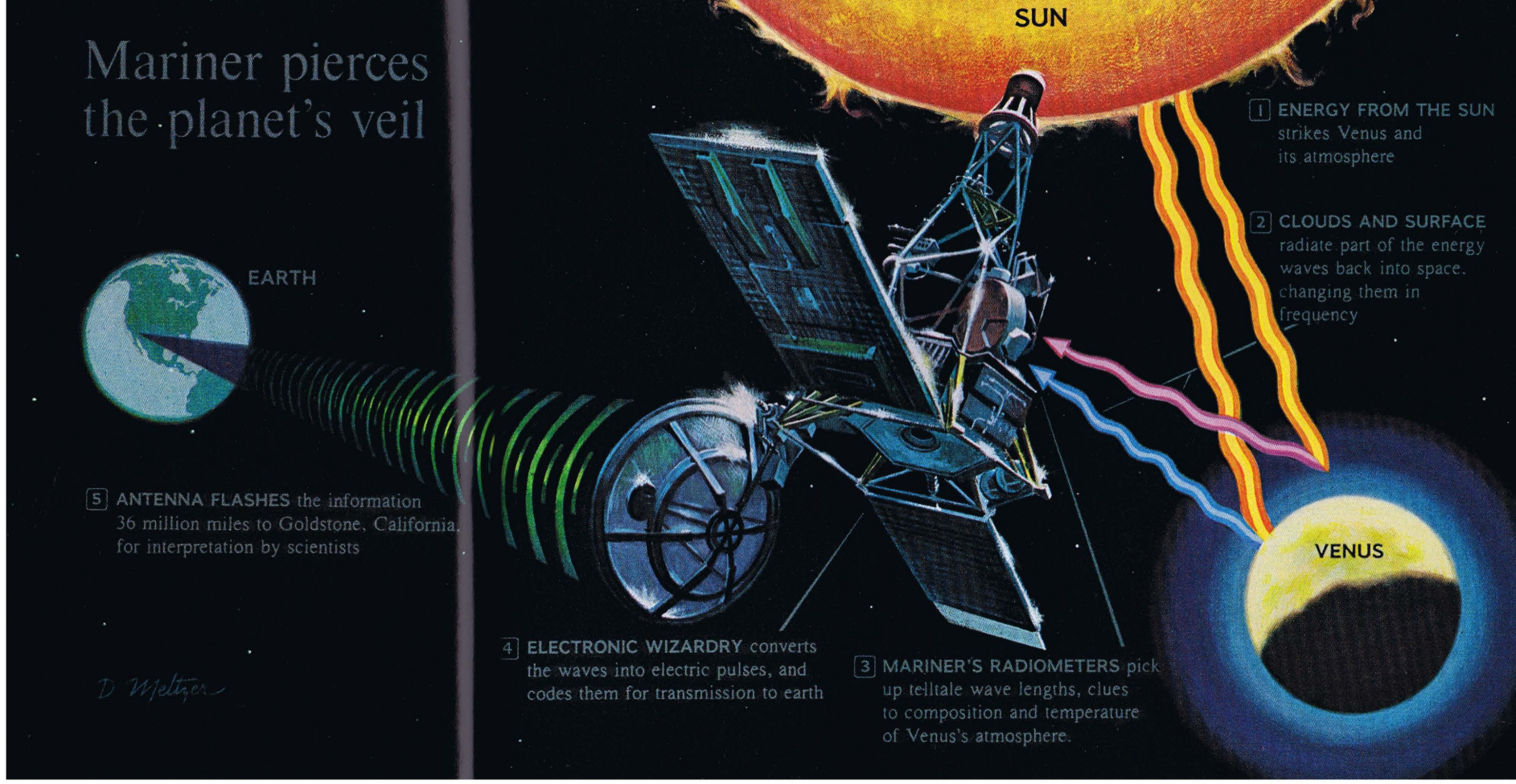
Only two bits of cosmic dust were detected along the way, indicating that these specks of matter are only one ten-thousandth as plentiful as those found near our planet—a reassuring finding for spacecraft designers.

And, as it sped onward, the craft was giving scientists data that should provide the most accurate estimate yet of the mean distance from earth to sun. This so-called astronomical unit—nearly 93 million miles—is the vital measuring stick of our solar system.

For a month Mariner cruised without incident, its electronic brain sampling each instrument in turn and relaying its coded findings to earth.

Suddenly on October 31, the electric power aboard dropped alarmingly. In charge at the Jet Propulsion Laboratory control room in Pasadena was Space Flight Test Director Tom Bilbo. His desk, one of three so equipped, held three television consoles showing raw data as it came in. On a board nearby, assistants posted decoded information. These numbers left no doubt; the craft was in trouble.

Bilbo called Jack James, who happened to be in Tucson, Arizona. For several hours on the telephone they discussed the possibilities. It appeared that one solar panel might have shorted out. They decided to turn off the four instruments to conserve Mariner's power.



James rushed to Pasadena to check solar panels identical to Mariner's. The city was cloud-covered; he sent engineers with panels in a plane to "look for sunlight." Finding some in the Mojave Desert, they landed and began tests. They duplicated Mariner's symptoms by causing a short circuit.

After a week of experiment, it was decided that the remaining panel could put out enough power to run the whole craft, since it was now nearer the sun. Orders to turn on the four instruments were prepared. The orders were sent as planned—even though the trouble had mysteriously healed itself a few hours earlier.

The power failure, perhaps caused by a meteor hitting the panel, cost the mission a week's interplanetary data.

Now another problem loomed: Mariner had chills and fever. Some parts were colder than they should have been, some were hotter.

The heat was serious. No one knew exactly how much heat vital electronic systems would take. Also, the battery aboard might explode, wrecking the craft. James called the battery designer. "What is the maximum temperature that our battery will withstand?"

Back came the only possible answer. "I don't know. I can only tell you how far we tested it: 120° Fahrenheit."

Every day, as the craft got nearer Venus, and nearer the blazing sun, the heat in vital parts increased. On December 5, the battery reached its test limit. The vital earth sensor hit 130°. There were still nine days to go.

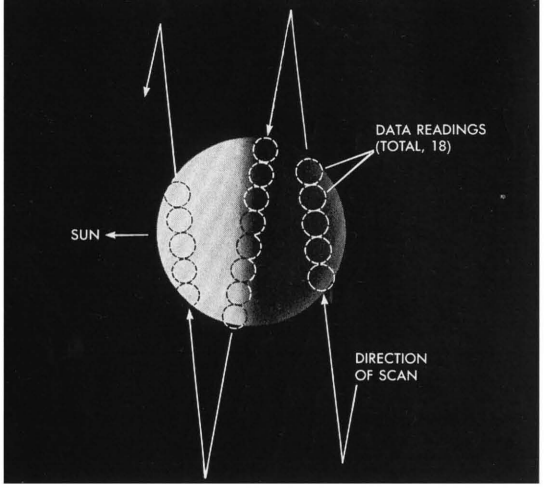
Earth Sensor Goes "off the Dial"

Already, the instruments that were to scan the planet seeking temperature and atmospheric make-up were performing imperfectly. As a result, there would be only 3 scans by these radiometers, instead of 15 (next page).

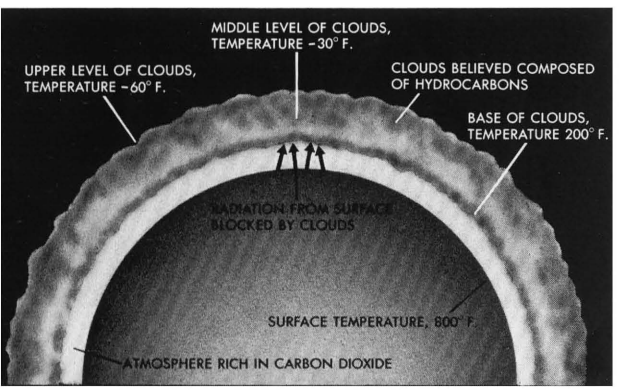
As I talked to the people in the control room during those last uncertain days, I found they divided into optimists ("It's been working 106 days; it'll work three more") and pessimists ("I'm afraid of that earth sensor").

One and all asked the same question when they came to work: "How's the bird?" Each day the answer was "fine," or "ticking away." But each day the temperatures were posted, and each day they were higher.

Then, abruptly, temperature data from the



Scanning Venus three times, Mariner's nodding instruments probed night side, sunrise line, and finally the day side. They reported solid clouds that produce a "greenhouse effect," blanketing the surface in a heat of 800° F. (below).



ADAPTED FROM DRAWINGS BY NASA

vital earth sensor became meaningless—it was so hot the reading was "off the dial." Now neither optimists nor pessimists would have any figures to base their hopes or worries on.

The night of December 13, 1962, was crucial. At that time Mariner was supposed to turn on the two radiometers, by a command stored in its electronic brain. About 50 persons manned the control room, quiet and tense, at 11:21 p.m., waiting for the signal. None came. Battery temperature had reached 129° F. Earth sensor temperature: unknown.

Mariner would again be in position to turn on its instruments by itself at 2:40 a.m. Everyone waited. Again nothing happened.

There was one more chance. The experiments might be turned on from earth through the Goldstone antenna. Venus would "rise" over Goldstone at 4:16 a.m. Everyone waited.

Goldstone tracked Mariner for half an hour to make sure of its aim, then gave the order. Mariner was so far away from earth that the radio command, traveling at the speed of light, took more than 6 minutes to reach the craft and return. When the coded answer flashed back, it reported that Mariner had obeyed. And so, after 6 minutes and 30 seconds of utter quiet, the control room exploded with laughter and clapping.

Now, if only the solar heat didn't wreck something, success seemed sure. And, at 10 seconds before 1 p.m. on December 14, 1962, a still-vocal Mariner reached its closest point to Venus—21,700 miles—and sent its information 36 million miles back to its creators.

Venus – Searing, Dry, and Gloomy

After months of study, Mariner scientists reported to the world. Their findings, with other experiments, round out a fascinating picture of our nearest neighbor planet.

The atmosphere is hostile to man, rich in carbon dioxide, poor in water vapor and oxygen. Continuous cloud cover—15 to 20 miles thick and starting 45 miles above the surface—creates a "greenhouse effect," letting sun energy reach the planet, but preventing much of the heat from escaping into space.

Though astronomers had assigned a temperature of 600° to the surface, Mariner raised this estimate 200°. The searing surface is apparently dry and granular, perhaps sandy. Over it, slow winds circulate dense gases. Compressed in an atmosphere 10 to 20 times heavier than ours, the gases readily conduct heat around the planet. This explains why Mariner found no temperature difference between sunlit and dark sides.

The clouds keep Venus gloomy as well as hot. Apparently made up of hydrocarbons, they might be called smog.

Mariner's instruments found no planetary magnetic field at 21,700 miles from Venus, nor did they locate any bands of radiation like earth's Van Allen belt. The absence of such bands agrees with other observations that indicate a very slow—perhaps nonexistent—rotation of the planet. To an observer on Venus, if it does not rotate, the stars would seem to stand still, while the sun, rising in the west and setting in the east, would circle the planet in 225 days, the period of Venus's solar orbit. Thus Venus's day would equal its year.

As Mariner soars on in silent orbit around the sun, NASA's Dr. Homer E. Newell sums up the craft's verdict on an age-old question:

"With the surface of Venus hot enough to melt lead, the planet cannot support life as we know it." But biologists, he adds, reserve judgment on whether lower forms of life might exist in the planet's upper atmosphere.

"Investigation of that," the scientist concludes, "will have to wait until we get there."